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PRODUCTION AND RELEASE OF SEX PHEROMONE BY VIRGIN FEMALES OF THE SPOTTED BOLLWORM *EARIAS VITTELLA* (FABRICIUS) (LEPIDOPTERA : NOCTUIDAE)

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Age related sex pheromone production and temporal pattern of pheromone release by virgin females of *Earias vittella* were studied. Behaviour associated histological studies were also made to identify tissue source of the pheromone. Sex pheromone production increased with age till females became 4 day old and then there was a marginal decline. Histological and behavioural studies indicated pheromone producing cells to be present in the intersegmental region between the 8th and 9th abdominal segment dorsally and in a very large area of the 9 + 10 segment on all — dorsal, ventral as well as lateral sides. The females assumed a calling posture to release the pheromone, which was displayed by majority of the females in a single bout. Calling was restricted mostly to the terminal two hours of scotophase of a 14L : 10 D photoperiodic cycle; however, some females also called during the hour preceding and succeeding this period.

(*Key words:* *Earias vittella*, sex pheromone production, age, calling, sex pheromone gland)

INTRODUCTION

Utility of sex pheromones in the control of insect pests has given an impetus to the studies on pheromone related behaviour of insects. The spotted bollworm, *Earias vittella* (Fabricius) is an important pest of cotton and okra and its females release a six component sex pheromone (CORK *et al.*, 1988) to attract males. TAMHANKAR *et al.* (1989) have reported on the various endogenous factors that influence the response of males of this species to its sex pheromone. Information on aspects of sex pheromone production and its release is however lacking. This paper reports results of studies on the age related sex pheromone production, identification of pheromone source and temporal pattern of pheromone release of virgin females of *E. vittella*.

MATERIALS AND METHODS

The insect colony was maintained in the laboratory with okra fruit as larval food at 28° C ± 1° C. The method of insect handling and ageing was similar to that described earlier (TAMHANKAR *et al.*, 1989). Insects always remained in a 14 L : 10 D photoperiodic cycle and experiments concerning behavioural studies were generally conducted during the second half of the scotophase, as adults of this species are reproductively active only during this period (TAMHANKAR, 1986).

Pheromone production:

Terminal abdominal segments from 20 females of a particular age were cut during the last hour of scotophase and these were steeped in 1 ml methylene chloride held in a glass vial (1cm dia × 4.0 cm height) for 15 min. With the help of a glass syringe this extract

was transferred to a glass stoppered, graduated, conical interior glass tube. The glass vial containing the cut abdominal tip was washed once with methylene chloride (0.5 ml) and the washing was also similarly transferred. The extract thus obtained was stored at —20°C. No extract was stored for more than 5 days. Just before use, the total volume of the extract was reduced to 0.2 ml by evaporating the solvent under a stream of nitrogen. Ten microlitre of this extract represented one female equivalent (FE) of pheromone. Sex pheromone extracts were prepared from females of various ages from freshly emerged stage onwards, till an extract from a particular age female showed a decline in potency. One FE sex pheromone from females of each age was bioassayed in a 'T' olfactometer for its potency to attract males according to the method described by TAMHANKAR *et al.* (1989). Five males (4 day old) were used per bioassay which was replicated 5 times and the assays were conducted during the last hour of scotophase.

Pheromone source:

During the last hour of scotophase legs and wings of a few 4 day old virgin females were removed and the specimens were immersed in the fixative alcoholic Bouins. The thorax and abdomen of the specimens were pricked with a minuten pin several times to increase penetration of the fixative. The specimens remained under reduced pressure (300 mm Hg) for at least 24 hours, after which they were dehydrated with ethanol, cleared in methyl benzoate followed by benzene and infiltrated with paraffin (60° C–62° C). Serial, longitudinal and transverse sections were cut at 5 μm which were stained with Delafields' haematoxylin and eosin.

Proof that the tissues (of the terminal abdominal segments), indicated to be glandular by histological studies, contained pheromone was obtained by the following method. A calling female was caught in a pair of forceps and the abdominal portion was slightly compressed so that the terminal segments protruded. The tip of a pin was independently rubbed over the segments in question and the tip was presented to the males caged in a plastic container (6.5 cm dia × 6 cm height) with perforated screw cap. The behaviour of the males before and after the presentation of a blank and treated pin was observed.

Pheromone release:

Sixty freshly emerged virgin females were confined individually in plastic containers and observations on their behaviour were taken during the second half of scotophase at 15 min interval. These females were watched to find out whether all the females initiate calling every day. If a female was observed initiating calling on a day, it was not further observed. These observations were taken on 1, 2, 4 and 6 day old females, besides the freshly emerged ones.

On day 4, twenty females from the above lot that initiated calling, were observed at 5 min interval. Observations on calling bout and bout length were recorded. A bout was defined as one period of continuous calling. Observations during the scotophase continued even if a female stopped calling. During photophase, when no female called for a period of one hour observations were discontinued.

RESULTS AND DISCUSSION

Pheromone production:

Pheromone extract from freshly emerged females elicited least attraction from males

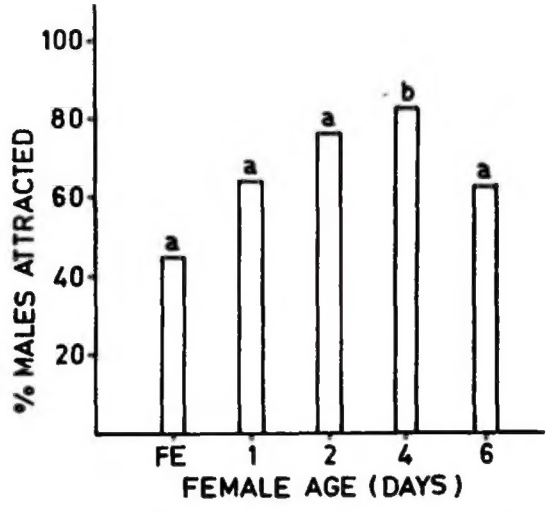

Fig. 1. Potency of pheromone extracted from virgin females of *Earias vittella*. (Means with the same letter are not significantly different at $P=0.05$. ANOVA - Duncan's multiple range test. ARCSIN transformations used for statistical analysis).

(Fig. 1). As the age advanced, the potency of the pheromone to attract males increased and extract from 4 day old females elicited maximum attraction. The potency of the extract from 6 day old females indicated a marginal decline in pheromone production. Similar age related changes in sex pheromone titre have been observed in other species belonging to family noctuidae (SHOREY *et al.*, 1968; SNIR *et al.*, 1986; RAINA *et al.*, 1986). TAMHANKAR *et al.* (1989) have earlier observed an age related increasing pheromone responsiveness amongst males of *E. vittella* till they became 4 day old. Similar pattern of increasing attractiveness amongst females indicates a well synchronized process of reproductive maturation of both sexes in *E. vittella*.

Pheromone source:

Observations of a large number of sections of the abdominal segments showed that the intersegmental membrane between the 8th and 9th abdominal segment on dorsal side and almost the entire 9+10 abdominal segment on the dorsal and ventral side (Fig. 2A) possessed epidermal cells considerably enlarged than were found in case of the other segments. Lateral continuity of these cells in the 9+10th abdominal segment was also indicated (Fig. 2B). These cells were similar in appearance to the ones found in sex pheromone glands of other Lepidoptera i.e., cuboidal to columner in shape with large nuclei and a cuticle varying in the thickness. The area around ovipositor also appeared glandular.

Normally the abdominal segments - 8th onwards - are telescoped inside the body and when protruded outside the intersegmental fold between 8th and 9th segment would bulge out and the entire 9+10 segment would form a ring like structure. Separate swabbings of these glandular areas by a pin and exposing the pin to males released in them a typical pheromone response behaviour i.e., wing flutter, extrusion of abdominal tip scent brushes and in some cases copulatory attempts. Response of

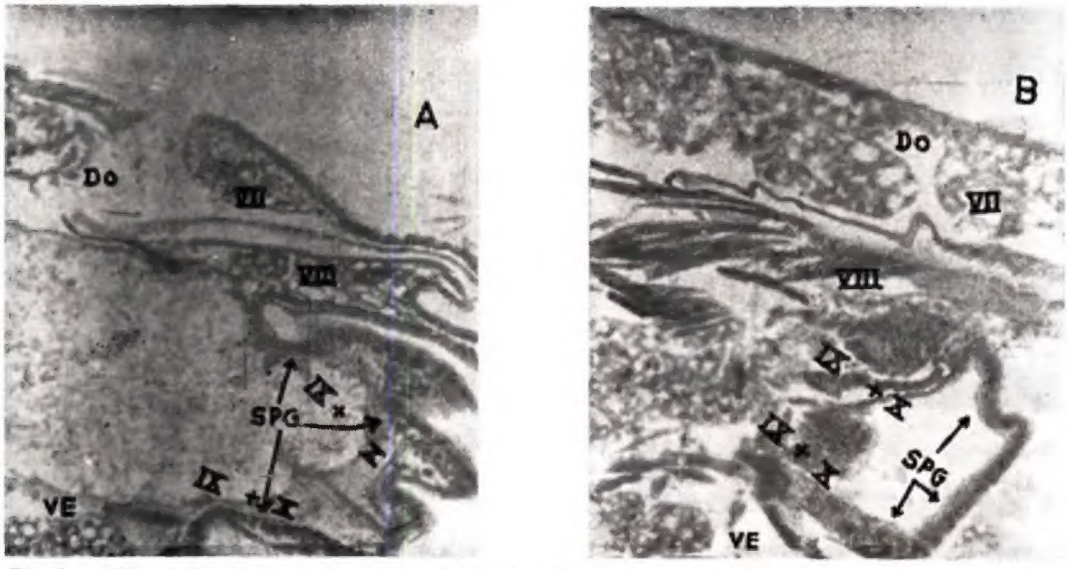

Fig. 2. A&B. Microphotographs of longitudinal sections of abdominal segments of *Earias vittella* females showing sex pheromone producing cells. (DO = dorsal side; VII, VIII, IX, X = segment numbers; SPG = sex pheromone gland cells; VE = ventral side). Fig. A shows all the areas that posses pheromone producing cells and B shows lateral continuity of these cells.

males to the pin swabbings from the two areas (dorsal and ventral) appeared to be similar. The area around ovipositor being too small could not be tested precisely. Sex pheromone gland in female Lepidoptera is normally found in the intersegmental region between the 8th and 9th abdominal segments (PERCY & WEATHERSTON, 1971) but it can be located elsewhere also (MCFARLANE & EARLE, 1970; CHOW *et al.*, 1976). There is some variation in the location of the sex pheromone gland in the various subfamilies of family noctuidae. In Plusiinae it is located in the intersegmental region (ISR) between the 8th and 9th abdominal segment dorsally (JEFFERSON *et al.*, 1968). In Amphypyriinae it is located ventrally in the same ISR (JEFFERSON *et al.*, 1968) or consists of a ventral area around ostium bursae and a ring shaped area around ovipositor, almost as if the two intersegmental membranes (between 7 and 8 and between 8 and 9+10) are modified (SRENG & SRENG, 1988). In cuculinae it is a protrusible ring between 8th and 9th segment (URBHAN, 1913). In Heliothinae it consists of a ventrolateral chevron in the intersegmental membrane between abdominal segments 8 and 9+10 besides a second glandular area in the dorsal valves (AUBREY *et al.*, 1983; TEAL *et al.*, 1983). *E. vittella* belongs to subfamily Chloephoriinae and the earlier

Fig. 3. Calling female of *Earias vittella*.

description would indicate it to possess distinctiveness from other subfamilies in the location of the sex pheromone gland.

Pheromone release:

For pheromone release the females assumed a peculiar posture named as 'calling' in insects. TAMHANKAR (1986) has found *E. vittella* females in calling posture to be attractive to males in bioassays. During calling (Fig.3) the ovipositor was protruded outside the abdomen by the females and was directed ventrally. This was accompanied by a characteristic stance wherein anterior of the body was held low to the substrate, posterior raised by extension of metathoracic legs and a slight raising of the wings, which remained motionless. During calling the ovipositor was slowly extended and retracted at regular intervals. In some females, scent marking behaviour as recorded by COLWELL *et al.* (1978) for *P. gossypiella* was also observed.

Out of the sixty females observed, 38.3% females called on the day of emergence. Thereafter on days 1, 2, 4 and 6 after emergence, respectively 83.3, 96.6, 95.0 and 90.0 percent females were found to initiate calling. The mean time of initiation of calling, for females of various ages mentioned earlier was respectively 47, 90, 83, 120 and 125 min before the initiation of photophase. Observations on calling behaviour of 4 day old females revelaed that out of the 20 females observed, 7 females had bouts of calling in the range of 2–4 whereas the remaining 13 had only one bout of calling (Fig. 4). The bout lengths varied from 5 to 60 min for females calling in multiple bouts and from 15 to 205 min for females that called only in a single bout. The

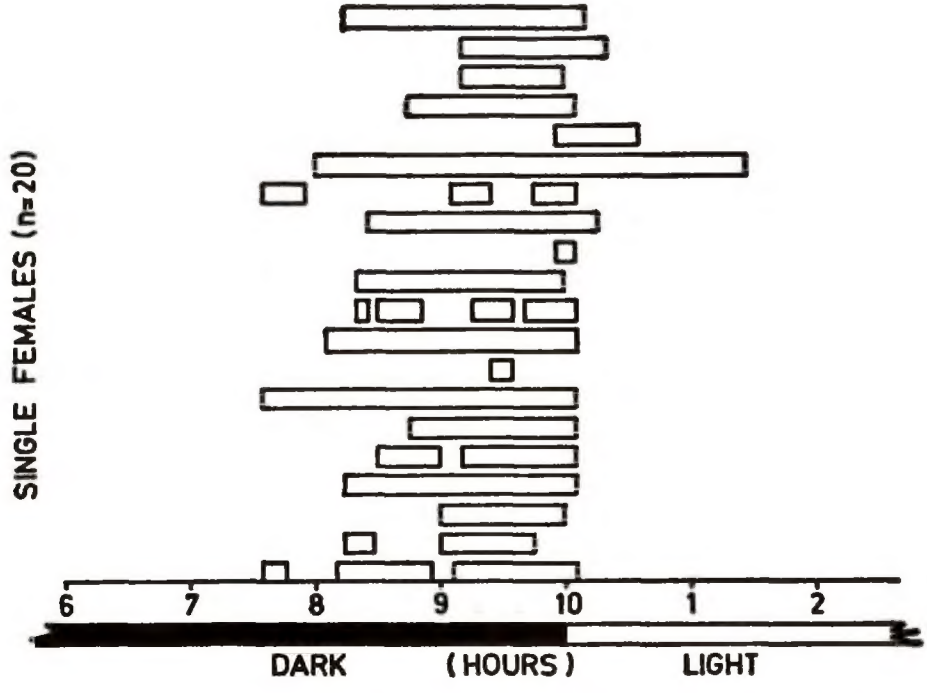

Fig. 4. Temporal pattern of calling of virgin females (4 day old) of *Earias vittella*.

earliest a female initiated calling was at 7 h 35 min after the initiation of scotophase and termination of calling was found to be as late as 1 h 25 min after the onset of photophase. Majority of the females were however found to terminate calling within 5–10 min after the onset of photophase. Peak calling activity of the females was recorded during the last hour of scotophase and during this period all the females were found calling.

As against some noctuids which exhibit several bouts of calling during one scotophase (SOWER *et al.*, 1971; SWIER *et al.*, 1976), majority of the *E. vittella* females called in a single bout. As the reproductive activity of this species is restricted to only a short period in the terminal part of scotophase, perhaps a stable and continuous source of pheromone release ensures maximum chances of meeting of both the sexes.

Results from our studies on pheromone production and release indicate that, in general, the females of *E. vittella* are not ready to mate at the time of emergence but become so by the time they are 2–4 day old. At this time pheromone production and calling reach their peak. As in other Lepidoptera, in this insect also, the source of pheromone is a glandular tissue. Its location is in the dorsal intersegmental region between the 8th and 9th abdominal segment and if not entire, at least a very large area of the 9+10th segment. In this region the gland is continuous on the lateral side.

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OVICIDAL ACTIVITY OF PERMETHRIN AND DELTAMETHRIN ON MOSQUITOES

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Laboratory treatment of the eggs of various age groups of the three species of mosquitoes, *viz.*, *Aedes aegypti*, *Culex quinquefasciatus* and *Anopheles stephensi* with two synthetic pyrethroids, permethrin and deltamethrun, caused only moderate ovicidal activity *per se* but inflicted delayed effects such as high larval and low pupal and adult mortality. Deltamethrin proved to be 10 times as toxic as permethrin against the eggs of these mosquitoes. The eggs of *An. stephensi* were found to be the most susceptible, followed by *Ae. aegypti* and *Cx. quinquefasciatus*. The age of the eggs and the duration of treatment also influenced the ovicidal activity.

(*Key words:* permethrin, deltamethrin, ovicidal activity, mosquitoes)

INTRODUCTION

Photostable synthetic pyrethroids such as permethrin and deltamethrin are recognised as potent alternative insecticides to replace hitherto employed organochlorine and organophosphorus insecticides in mosquito abatement programmes due to their excellent larvicidal, pupicidal and adulticidal properties (DARWAZEH & MULLA, 1974; PRIESTER *et al.*, 1981; DAS *et al.*, 1982; MULLA & DARWAZEH, 1985; THOMAS & PILLAI, 1986). Though some pyrethroids show promise as ovicidal compounds mainly against lepidopterous insects (TYSOWSKY & GALLO, 1977; CHALFANT *et al.*, 1979; PITTS & PIETERS, 1980; GIST & PLESS, 1985), their ovicidal potency against mosquito eggs is not fully known. Therefore, the objective of the present studies was to assess the ovicidal efficacy and delayed effects of permethrin and deltamethrin against the eggs of three medically important speceis of mosquitoes, *Aedes aegypti* L., *Culex quinquefasciatus* Say and *Anopheles stephensi* Liston.

MATERIALS AND METHODS

Eggs were drawn from mosquito colonies of *Ae. aegypti*, *Cx. quinquefasciatus* and *An. stephensi* maintained in our insectary at a temperature of 28 ± 1°C and 80 ± 5% relative humidity with a photoperiod of 14 h of daylight and 10 h of darkness (KUMAR *et al.*, 1991). Freshly laid eggs 0 to 6 h old and 0 to 18 h old were collected separately, by providing ovitraps in mosquito cages from 1000 h to 1600 h for obtaining 0 to 6 h old eggs and 1600 h to 1000 h overnight for collecting eggs of 0 to 18 h. Ovitraps were kept in the cages 2 days after the female mosquitoes were given blood meal.

The two pyrethroids, permethrin [3-phenoxybenzyl-3- (2, 2-dichlorovinyl) -2, 2-dimethyl cyclopropane carboxylate; *cis*: *trans* isomers - 20: 80] and deltamethrin [(S) - α-cyano-3-phenoxy benzyl *cis* - (1R) -3- (2, 2-dibromovinyl) -2, 2-dimethyl

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cyclopropane carboxylate; 98.8% pure] were obtained from Roussel Uclaf, India.

Stock solutions of the two insecticides were prepared in ethanol. The eggs were exposed to graded doses of the insecticides by adding 1 ml of the stock solution after appropriate dilutions to 249 ml of water in a 16-oz jar in order to obtain the desired concentrations. Only 1ml of ethanol was added in control experiments.

In case of *Ae. aegypti* and *An. stephensi*, the eggs are laid on filter paper lining provided in the ovitrap. These filter paper strips containing eggs after scoring were immersed in insecticide-treated water. However, in *Cx. quinquefasciatus*, egg-rafts were carefully removed on a piece of filter paper with a brush and eggs were counted and put into the treated water. Eggs of the age group 0 to 6 h were exposed for 18 h, while eggs of the age group 0 to 18 h were exposed for 6 h and 18 h to permethrin and deltamethrin, separately. In each treatment, a minimum of 100 eggs were used. Parallel control experiments were set up and each experiment was replicated twice.

After the exposure, the eggs were sieved through muslin cloth, thoroughly rinsed with tap water and left in enamel bowls filled with dechlorinated water for hatching. The per cent egg mortality was calculated on the basis of per cent nonhatchability of the eggs. The live larvae were reared in large enamel trays filled with dechlorinated water and fed on finely ground dog biscuits and yeast in the ratio of 3:2 (KUMAR *et al.*, 1991). The larval mortality was assessed after every 24 h interval till pupation. The number of pupae formed were scored and kept in small enamel bowls in empty mosquito cages for adult emergence. The number of adults emerged were counted and those with incomplete emergence were considered as dead. From the data, the egg, larval, pupal/adult and cumulative mortality were calculated.

RESULTS

The treatment of eggs of mosquitoes with permethrin and deltamethrin caused embryonic death resulting in failure to hatch the eggs. In addition, the treatments had deleterious delayed effect in causing high larval mortality and moderate pupal or adult mortalities in the larvae hatched out of the treated eggs. The mortality data of the egg treatments is given in Table 1.

In general, deltamethrin was about 10 times as toxic as permethrin in causing either egg mortality or delayed mortality in larvae or adults (Table 1). Egg mortality *per se* in any of the treatments did not go beyond 50% even with the highest concentration of permethrin (10 ppm) or deltamethrin (1 ppm). However, the larvae which hatched out from the treated eggs showed much higher levels of mortality in all the treatments. Also, the treatments produced low to moderate levels of pupal mortality or adult mortality at the time of adult emergence.

Treatment of eggs of 0 to 6 h was more effective in inducing higher rates of mortality as compared to eggs of 0 to 18 h treated for 6 or 18 h. Shorter duration of treatment was decisively inferior to longer exposure to insecticides at the egg stage. The eggs of *An. stephensi* were more susceptible to permethrin, while eggs of *Cx. quinquefasciatus* were the least susceptible. Exposure to 0.1 ppm of permethrin for 18 h of eggs of 0–6 h caused 80–90% cumulative mortality in different life stages of all the three species of mosquitoes. Almost identical results were obtained in similar treatments

with deltamethrin at a dose of 0.001 ppm (Table 1). Unlike permethrin, deltamethrin was equitoxic to all mosquitoes in causing more or less similar toxicity in different species of mosquitoes. Exposure to 0.01 ppm deltamethrin for 18 h of eggs of 0–6 h elicited about 95% cumulative toxicity, though the egg mortality *per se* did not increase beyond 32%.

The results showed similar trend with regard to treatments of 0–18 h old eggs exposed for 6 h or 18 h to permethrin or deltamethrin (Table 1). Treatment for 6 h was inferior to 18 h treatment in all the cases. Also, 18 h exposure of older eggs was less effective as compared to similar treatment of eggs of lower age (Table 1).

DISCUSSION

It is evident from the present data that exposure of eggs of mosquitoes to both permethrin and deltamethrin elicit not only egg mortality but also delayed effects resulting in mortality at larval, pupal and adult stages. Though ovicidal activity *per se* is only moderate, an important finding is that the larvae which hatch out of the treated eggs immediately succumbed to death. The pupal or adult mortality was significantly less as compared to larval or egg mortality. The present data also indicate that deltamethrin is far superior to permethrin in causing ovicidal activity and delayed toxicity. However, RETTICH (1980) found that permethrin emulsions had no ovicidal action against the egg of *Cx. pipiens molestus*.

Exposure of freshly laid eggs was more effective than the older eggs. MIURA *et al.* (1976) showed that the age of the embryos at the time of treatment played a crucial role with regard to the effectiveness of the chitin synthesis inhibitor, dimilin to *Cx. quinquefasciatus*. Exposure time also has a crucial role in causing toxicity. According to SMITH & SALKELD (1966), differences in susceptibility to ovicides are due to differential rates of uptake, penetration through the chorion, conversion to active inhibitor, detoxication and failure of the toxicant to reach the target. GROSSCURT (1977) observed that the efficiency to act on the embryo inside the egg shell depends on an efficient penetration of the insecticide, which, in turn is influenced by the exposure period. Total inhibition of egg eclosion when eggs were directly exposed to high concentrations of the compounds indicated more entry of the chemical inside the egg shell, which affected the embryogenesis (BROADBENT & PREE, 1984). Similarly, longer exposure periods also facilitated the increased penetration of the compounds into the shells, thus increasing their effectiveness.

The eggs of mosquitoes are found to be much more tolerant to the action of insecticides compared to larval stages. Insect eggs are covered with a shell which differs biochemically from the integument of the larvae, and the difference in penetration of the insecticide through the egg shell and the larval integument is reflected in the observed toxicity differences. It may be concluded that deltamethrin and permethrin even when treated at egg stage can inflict high cumulative mortality in *Ae. aegypti*, *Cx. quinquefasciatus* and *An. stephensi* due to their ovicidal activiy and delayed effects at other life stages of mosquitoes.

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TABLE 1. Egg, larval and pupal/adult mortality of *Ae. aegypti*, *Cx. quinquefasciatus* and *An. stephensi* when eggs of either 0–6 or 0–18 h were treated with permethrin/deltamethrin for 6 h and 18 h.

Species	Permethrin (ppm)	Eggs 0–6 h (Treated for 18 h)				Eggs 0–18 h (Treated for 6 h)				Eggs 0–18 h (Treated for 18 h)			
		*Egg mortality	Larval mortality	Pupal/adult mortality	Cumulative mortality	*Egg mortality	Larval mortality	Puapl/adult mortality	Cumulative mortality	*Egg mortality	Larval mortality	Pupal/adult mortality	Cumulative mortality
Ae. aegypti	0	15.5	0.7	2.4	18.6	14.0	1.3	4.3	19.6	12.0	8.1	7.6	27.7
	0.01	19.5	33.3	21.8	74.6	15.5	31.6	14.5	61.6	17.5	33.3	18.8	69.6
	0.1	26.0	48.3	12.6	86.9	21.5	41.7	15.3	78.5	21.0	47.0	17.3	85.3
	1.0	39.5	40.5	17.3	97.3	30.0	40.6	19.8	90.4	33.5	44.3	16.7	94.5
	10.0	41.5	48.3	10.2	100.0	35.0	52.6	10.6	98.2	36.5	49.5	14.0	100.0
Cx. quinquefasciatus	0	12.0	7.4	1.9	21.3	7.0	4.5	0.4	11.9	6.0	1.5	3.1	10.6
	0.01	16.5	42.7	6.9	66.1	9.5	30.2	13.9	53.6	14.5	35.1	13.6	63.2
	0.1	23.5	44.1	11.7	79.3	20.5	31.3	20.5	72.3	23.0	34.3	17.2	74.5
	1.0	33.0	42.4	20.5	95.9	26.5	40.9	20.9	88.3	29.0	43.6	17.9	90.5
	10.0	37.0	51.8	11.2	100.0	31.0	51.3	15.5	97.8	35.5	52.8	10.2	98.5
An. stephensi	0	15.0	4.3	0.2	19.5	11.0	10.5	6.4	27.9	8.5	1.1	7.8	17.4
	0.01	24.0	41.8	13.8	79.6	17.5	32.1	22.1	71.7	19.5	38.1	20.3	77.9
	0.1	29.5	50.5	10.5	90.5	24.5	47.6	9.5	81.6	27.0	51.0	11.3	89.3
	1.0	36.5	53.0	10.5	100.0	33.0	45.3	17.7	96.0	34.0	49.9	13.7	97.6
	10.0	44.5	55.5	0.0	100.0	39.5	48.9	11.6	100.0	42.0	53.6	4.4	100.0
	Deltamethrin (ppm)												

Ae. aegypti	0	10.5	1.7	5.3	17.5	10.0	3.6	1.4	15.0	7.5	6.1	5.3	18.9
	0.001	18.5	36.0	30.9	85.4	14.5	25.3	27.1	66.9	17.5	27.5	30.3	75.3
	0.01	30.0	31.3	34.6	95.9	22.0	35.6	24.9	82.5	26.5	33.3	32.1	91.9
	0.1	32.5	57.7	9.8	100 0	29.5	56.9	8.6	95.0	31.5	58.3	10.2	100.0
	1.0	47.5	52.5	0.0	100.0	44.5	55.5	0.0	100.0	46.0	54.0	0.0	100.0
Cx. quinquefasciatus	0	17.5	11.7	9.8	39.0	12.5	8.8	0.6	21.9	16.0	4.6	8.6	29.2
	0.001	19.0	28.6	34.7	82.3	16.5	14.8	29.2	60.5	17.5	21.2	32.9	71.6
	0.01	27.0	32.5	35.5	95.0	20.5	29.1	28.9	78.5	25.0	31.3	34.7	91.0
	0.1	29.5	59.8	6.6	95.9	26.0	48.8	14.3	89.1	27.5	53.1	11.6	92.2
	1.0	43.0	57 0	0.0	100.0	40.0	45.5	5.5	100.0	40.5	56.3	3.2	100.0
An. stephensi	0	14.5	2.1	3.2	19.8	10.5	7.1	4.5	22.1	11.5	1.3	11.7	24.5
	0.001	24.0	39.9	20.6	84.5	19.5	23.3	34.8	77.6	21.0	31.7	26.5	79.2
	0.01	31.5	38.7	25.6	95.8	25.0	36.9	29.2	91.1	28.5	38.1	25.8	92.4
	0.1	38.0	54.0	8.0	100.0	32.5	46.7	19.5	98.7	36.0	54.3	9.7	100.0
	1.0	50.0	50.0	0.0	100.0	46.0	54.0	0.0	100.0	48.5	51.5	0.0	100.0

•Percent non-hatchability.

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CARBOHYDRATES IN THE ACCESSORY REPRODUCTIVE GLAND OF ADULT MALE VARIEGATED GRASSHOPPER *ZONOCERUS VARIEGATUS* L. (ORTHOPTERA: ACRIDOIDEA: PYRGOMORPHIDAE)

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Studies on carbohydrates in defined insect tissues is scanty. Sugars in the accessory glands of adult male *Zonocerus variegatus* were determined by paper – and gas chromatographic analyses at different periods of development. Quantitative determination of sugars in the accessory glands reveals the presence of galactose, glucose, fructose, cellobiose, trehalose and lactose in different concentrations between 0 and 42-day-old insects. Gas chromatographic analysis shows the presence of galactose in 0, 14, 21 and 28 day-old adult insect and glucose in day 14 insect. The presence of sugars in the accessory glands of *Z. variegatus* suggests an energy source for the spermatozoa during mating.

(*Keywords* : *Zonocerus variegatus*, adult, accessory glands, development, sugars)

INTRODUCTION

Although proteins and carbohydrates were regarded as ubiquitous components of the accessory glands of insects (LEOPOLD, 1976), more work has been done on the analysis of protein components of the accessory glands of several species of insects (CHEN, 1984). To date, very few data is available concerning the sugar constituents of the male accessory gland secretion of insects. BLUM *et al.* (1962) demonstrated the presence of fructose, glucose and trehalose in the bee *Apis mellifera* leaving the hive and returning after flight. Inositol is supposed to be the main carbohydrate present in the accessory gland complex of *Periplaneta americana* (LEOPOLD, 1976). BAUMANN (1974) reported the presence of glucose and xylose as the important components of factors that stimulate egg maturation and oviposition in the female insect. The present investigation was undertaken to study the carbohydrates in the accessory glands of *Zonocerus variegatus* (Linnaeus) including changes at different periods of adult development.

MATERIALS AND METHODS

Newly emerged adult (day 0) *Zonocerus variegatus* were removed from nymphs maintained on the shoot of *Chromolaena odorata* (L.) King and *Manihot esculenta* (Cranz). The males were reared in isolation of females on cassava shoot *M. esculenta.* The adult male grasshoppers were marked on the pronotum and on the forewings to determine their ages.

Gas liquid chromatography of sugars in the accessory glands

Accessory gland ethanolic extract (5 pairs of gland bundles per 0.5 cm^3) from 0, 7, 14, 21 and 28–day-old insects were used for the determination. The ethanolic extracts were heated with (STOX' Oxime-internal standard reagent in dry methanolic 1M hydrochloric acid for 6 hours at

85°C. The oxime derivatives were neutralised with silver carbonate and re-N-acetylated with trifluoroacetic acid. The dry samples were trimethyl silylated with a mixture of hexa Methyl disilazane (HMDS) and thereafter analysed by gas chromatography (CLAMP, 1974).

Paper chromatographic determination of sugars:

Accessory gland of adult insects at 0, 7, 14, 21, 28, 35 and 42 days of development were isolated in 80% ethanol (5 pairs of gland bundles per 0.5 cm^3). They were homogenised and centrifuged at 2,000g for 10 minutes and the supernatants were used for analysis in two replicates.

Chromatographic run:

80 μl of unhydrolysed extracts were analysed by one dimensional descending chromatography on Whatman No. 1 paper using n-butanol-acetic acid-water (4 : 1 : 1 v/v) solvent system for 18 hours overnight 20 μl of 1 gm/cm^3 solution of glucose, sucrose, trehalose, ribose, glucosamine, fructose, lactose, galactose, xylose and cellobiose were used as reference sugars.

Quantitative analysis:

After chromatographic run, the sugars were detected with alkaline silver nitrate solution (TREVELYAN *et al.*, 1950). The corresponding carbohydrate containing sections of undeveloped paper were cut out and eluted in 2 cm^3 of distilled water. 1.5 cm^3 of a saturated solution of anthrone in ethyl acetate and 6 cm^3 of concentrated sulphuric acid were added to the eluate. The absorbance of the anthrone complex was measured with a spectrophotometer at 580 nm, 30 minutes later. The concentration of the sugars was determined by comparing the values with standard curves prepared for the sugars detected.

RESULTS

Gas chromatographic determination of sugars:

The results of the gas chromatographic analysis of accessory gland sugars of 0, 7, 14, 21 and 28-day-old adult male

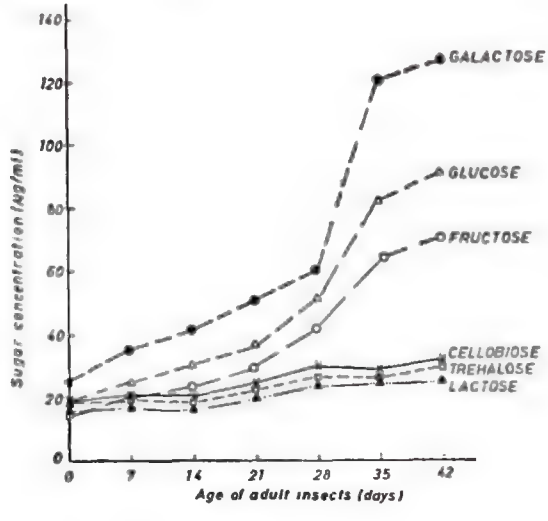

Fig. 1. Concentrations of carbohydrates in the ethanolic extracts of accessory glands of adult *Z. varigatus* from day 0 to 42 days of development.

TABLE 1. Concentration of carbohydrates in the ethanolic extracts of accessory glands of adult *Z. variegatus* at various stages of development.

Days of development	Carbohydate concentrations (μg)					
	Galactose	Glucose	Fructose	Cellobiose	Trehalose	Lactose
0	25.5	18.5	14.0	19.5	18.0	16.0
7	35.5	25.0	20.0	21.0	19.0	17.0
14	41.0	30.0	23.0	20.0	18.5	16.0
21	50.5	36.0	29.0	24.0	22.0	19.0
28	69.5	51.5	41.0	29.5	26.0	23.0
35	120.0	82.0	64.0	28.0	25.0	24.0
42	126.5	90.0	70.0	31.0	28.0	24.0

Values are means of two determinations.

Z. variegatus shows the following: glucose and galactose were detected in 0 and 7-day-old adult insects while the accessory glands at 14, 21 and 28-days of development revealed the presence of glucose.

Quantitative determination of sugars

The concentration of sugars in the ethanolic extracts of *Z. variegatus* from 0 to 42 days of development are shown in Table 1 and Fig. 1. The sugars increased in concentrations for galactose, glucose fructose, cellobiose, trehalose and lactose from day 0 to 42 days of development. There was gradual increase in fructose, glucose, galactose concentrations between 0 and 28 days and hereafter increased sharply up to 42 days of development. Cellobiose and trehalose occur at low concentrations with little chnages at every stage of development (0–42 days). Lactose concentrations profile is similar in those of cellobiose and trehalose in the accessory gland extracts. At every stage of development, galactose consistantly maintains the highest concentration of the six sugars detected in the ethanolic extracts of the accessory glands.

DISCUSSION

The concentrations of cellobiose, trehalose and lactose in the ethanolic extract of accessory glands of *Zonocerus variegatus* were consistently lower than those of galactose, glucose and fructose at various stages of development. In the present work, galactose, glucose and fructose concentration increased with age of the insects suggesting an increase in the sugar quantity with the development of the gland. Galactose and cellobiose are constituents of plant polygaccharides (PAZUR, 1970) and since adult Z. *variegatus* feeds regularly on cassava shoot, the high concentration of galactose in the gland is understandable. Insects do not have a source of trehalose in their diets, except *Drosophila* which feeds on yeast, and they are able to synthesize the sugar (WYATT & KALF, 1957). Since trehalose is synthesized in the haemolymph from glucose precursor (WANG & PATTON, 1969), it could be that the trehalose detected in the accessory glands of Z. *variegatus*

is selectively absorbed from the haemolymph. BLUM *et al.* (1962) reported the presence of glucose, fructose and trehalose in the haemolymph, testes and seminal plasma of the honey bee, *Apis mellifera*, as a source of energy for spermatozoa. MANN & LUTWAK-MANN (1948) have shown that in mammals, reproductive fructose is enzymatically produced in the accessory glands from glucose and it provides essential energy for the survival and motility of spermatozoa. The present study seems to suggest that some of these sugars which were also detected in the accessory glands of Z. *variegatus* serve as a source of energy for sperm motility in the mated female of the variegated grasshopper.

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ASPECTS OF REPRODUCTIVE BIOLOGY OF *TRATHALA FLAVOORBITALIS* (CAM.): A PARASITOID OF *LEUCINODES ORBONALIS* (GUEN.)

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Mating in the ichneumonid *Trathala flavoorbitalis* (Cam.), a larval parasitoid of many lepidopterans, reduces the preoviposition period and longevity significantly, while increasing the average fecundity from 50.2 to 74.3. Unmated females produce female progeny only, making *T. flavoorbitalis* a parthenogenetically thelytokus species. Multiple insertions of the ovipositor into the host body is frequent in oviposition. A single sting results in the laying of a single egg and the parasitization of 62% of the hosts attacked, whilst multiple stinging with 3-6 eggs laid per host, leads to a parasitization level of almost 90%. However, in the multiple parasitized hosts only a single parasitoid larva, in the 2nd or 3rd instar, survived after the 8th day of parasitization. Thus, multiple stinging, although seemingly a wasteful phenomenon, is part of the reproductive biology of *T. flavoorbitalis*. Several aspects of this reproductive biology together with the ease with which this species can be mass reared make *T. flavoorbitalis* a likely candidate in the effective biocontrol of many lepidopterous pests.

(*Key words: Trathala flavoorbitalis*, *Leucinodes orbonalis*, single/multiple stinging, parasitism, oviposition, parasitoid development)

INTRODUCTION

Trathala flabvoorbitalis (Cam.) (Hymenoptera: Ichneumonidae) parasitizes many lepidopterous species throughout the world. It is widely distributed in the Orient and has been released in Hawaii (SWEZEY, 1926) and into several other states of the U.S.A. (BRADLEY & BURGESS, 1934), initially for the control of the European corn borer and next for the control of the oriental fruit moth. Subsequently, it has been found that in Hawaii alone about 30 species of lepidopterans are parasitized by *T. flavoorbitalis* (SWEZEY. 1915, 1919, 1929). It is parasitic on the following economically important pests: *Pyrausta nubilalis* Hbn., the European corn borer; *Omiodes accepta* (Butl.), the sugar cane leaf roller (SWEZEY, 1926); *Hymenia fascialis* Cramer, the Hawaiian beet web worm (VIERECK, 1911); *Lamprosema blackburni*, the coconut leaf roller (SWEZEY, 1934). In Sri Lanka, *T. flavoorbitalis* has been recorded from 17 different hosts (BEESON & CHATTERJEE, 1935; CHU & SHEN, 1937; THOMPSON, 1957), one of which is *Leucinodes orbonalis* (Guen.), the brinjal (*Solanum melongena*) shoot and fruit borer.

Currently much interest has been focused on *T. flavoorbitalis* as a potential biocontrol agent of the brinjal shoot and fruit borer (CAB Int. Inst., pers. comm.). Very little information, however, is available on its biology. BRADLEY & BURGESS (1934) described the immature stages and development,

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while CLARK (1935) described its status as a parasitoid of *Pyrausta nubilalis*. Studies were therefore initiated by us to elucidate the reproductive biology of the parasitoid reared on *L. orbonalis*. Our findings on oviposition, fecundity, parthenogenesis, progeny - sex ratio and the effects of single and multiple parasitization are reported here.

MATERIALS AND METHODS

Adults of *L. orbonalis* that emerged from pupae collected in the field on plants of *Solanum melongena* (L.) were maintained in the laboratory at 29° ± 2°C in wooden cages (30 × 30 × 30 cm) covered in net and provided with 10% sucrose solution. Eggs laid on the net cover of the cage were removed with a fine brush and held in Petri dishes until hatching. Larvae were placed on fruits of *S. melongena* (cultivar: purple lena iri) and reared until pupation.

Adults of *T. flavoorbitalis* were obtained on emergence from parasitized pupae of *L. orbonalis*, similarly collected from the field. In the laboratory these were held in wooden cages (30 × 30 × 30 cm) covered in muslin cloth and fed on 10% sucrose solution.

L. orbonalis larvae were parasitized in the laboratory by exposing fourth or fifth instars for 24 h to newly emerged female parasitoids held in glass jars (12 × 7 cm). Thereafter, these larvae were allowed to bore into brinjal fruits to continue development. On pupation, they were held until the emergence of parasitoids. Since only a single parasitoid emerges from a parasitized host pupae; by holding parasitized host pupae individually in separate vials (10 × 3 cm), it was ensured that any female emerging remained unmated, as long as necessary. When mated female parasitoids were required, pairs of newly emerged males and females provided with food, were held together in vials (10 × 3 cm) for a period of 4 days, after which the females could generally by considered to have mated (SANDANAYAKE, 1987).

Condition of the ovary : To study the development and the movement of eggs in relation to the age the female, unmated and mated females (the latter caged with males till necessary) 0.5 10, 15 and 20 days old were dissected and examined microscopically (10 × 10) for eggs. Ten mated and 10 virgin females of each age were examined in this manner.

Preoviposition period: One to 12 day old parasitoids (10 unmated and 10 mated females of each age) separately held in jars were used in the study. Starting with the day old parasitoids, a single 4th to 5th instar host larva was exposed to each parasitoid for 24 h. This procedure was repeated with 2 to 12 day old females, where each female was exposed to a fresh host. On exposure, behaviour of the parasitoids were carefully observed and any attempts at oviposition (stinging) recorded. Stung hosts were reared on brinjal fruits for 5 days, the incubation period of the parasitoid egg noted, then dissected and examined for parasitoid larvae.

Fecundity and longevity: Fecundity was investigated by exposing daily, 7 day old mated and unmated parasitoids (n=20); each separately to a fresh group of seven host larvae (3rd to 5th instars). Exposed host larvae reared on brinjal fruits were examined 5 days later for parasitoid larvae. This procedure was continued daily with each parasitoid until its death. Each female parasitoid was dissected immediately it died, and examined for unspent eggs that still remained in it. The realized fecundity of any experimental parasitoid was the total number of parasitoid larvae

found in all the host larvae exposed to it, during its entire life span. A record of the longevity of each parasitoid was also made.

Sex of progeny: Seven day old female parasitoids were used in the study. Throughout its life span, each of 10 mated and 10 virgin female parasitoids, held separately, was daily provided with groups of 10 larvae (5th instars). Exposed hosts were reared until pupation and the pupae were then held singly until parasitoid emergence. The sex of the progeny was also recorded.

Effect of single/multiple stinging: The effect of a single insertion of the ovipositor (stinging) by the parasitoid was examined by exposing a single host larva at a time to individual, 7 day old female parasitoids (n=100). On careful observation hosts stung just once were removed and examined five days later for parasitoid larvae.

Effect of multiple stinging was examined similarly, except that each parasitoid was allowed to sting the host several times during an exposure period of 30 min. Each of 10 female parasitoids were provided with 10 different host larvae, one at a time in succession. Each encounter lasting 30 min was carefully observed, the number of times each host was stung during its 30 min exposure was noted. Stung host larvae were dissected immediately after exposure and examined for parasitoid eggs.

A further batch of host larvae (n=2000) was similarly subjected to multiple stinging by parasitoids (20), one female parasitoid being provided as before, with a total of 10 host larvae one at a time in succession, each encounter lasting 30 min; and thereafter reared on brinjal fruits. Of those 200 multiple stung host larvae, 100 were dissected, each 4 days after it had been stung and examined for parasitoid larvae.

The remaining host larvae were used to study the further development of parasitoid larvae in multiple - parasitized hosts. They were dissected and examined in batches of 10 each day, the first batch on the 4th day after being stung, the second batch on the 5th day, and so on to the seventh batch on the 10th day after being stung, making a total of 70 thus examined. The balance 30 of these, multiple stung larvae were reared until emergence of the adults; host or parasitoid.

RESULTS

Condition of the ovary:

The ovary of a female parasitoid at emergence contained a few mature eggs (15–24) and very many immature ones. The number of mature eggs increased markedly with increasing age in both mated and unmated females (Table 1).

Between the 5th and 3rd day after emergence, eggs were observed to have moved down the oviduct into the ovipositor.

TABLE 1. Number of mature eggs observed in the ovary of *Trathala flavoorbitalis* females of different ages.

Age of female (days)	Mated females $\bar{x} \pm$ S.D.(Range)	Unmated females $\bar{x} \pm$ S.D.(Range)
0	21.0 ± 2.2 (18–23)	18.2 ± 2.8 (15–21)
5	55.6 ± 5.4 (51–61)	61.3 ± 4.9 (55–66)
10	72.7 ± 5.9 (67–79)	81.7 ± 4.2 (77–86)
15	94.7 ± 4.8 (89–101)	84.1 ± 6.3 (78–91)
20	75.9 ± 4.4 (72–82)	68.2 ± 5.6 (63–74)

All mean values significantly different at $P=0.05$.

The ovipositor of 15 day old parasitoids was full of eggs, while the jars which held 20 day old females contained eggs (20–40) deposited on the walls. Eggs of *T. flavoorbitalis* are creamy in colour, sausage shaped and measure 0.125– 0.15 mm in length and 0.03– 0.04 in breadth.

Preoviposition period:

When unmated and mated parasitoid females were provided with host larvae daily, a positive ovipositional response was elicited, generally only after the 6th day (mated females) and 9th day (unmated females) from eclosion and rarely on the 4th day (in certain mated females) (Table 2).

The age at which a female stung a host larva frequently was taken as the commencement of its oviposition period, provided this was confirmed by the detection, 5 days later, of parasitoid larvae in frequently stung hosts. The period prior to such frequent stinging behaviour was considered as the preoviposition period.

Fecundity and longevity:

Of the 120 host larvae exposed in groups to 20 individual parasitoids (10 mated and 10 unmated), 42.4% was parasitized by the mated and 56.7% by the unmated parasitoids. Each of these parasitized hosts dissected 5 days after exposure contained 0 to 5 parasitoid larvae. Fecundity of these parasitoids assessed on the number of larvae is given in Table 2. While the mean fecundity of mated female parasitoids (74.3) was significantly higher than that of unmated (50.2), the latter at death retained significantly larger number of unspent eggs (41.6) than mated females (11.3). Similarly the unmated females lived longer (30.2 days) than the mated (23.5 days).

Sex of the progeny:

Only female progeny (n=41) emerged from eggs laid by unmated parasitoids (n=10) while both male and female progeny emerged from eggs laid by mated parasitoids. Of a total of 162 progeny that emerged from hosts parasitized by 10 mated females parasitoids, 99 were males while 63 were females (1.6:1 sex ratio). Closer examination of the sequence in the laying of male or female producing eggs by individual, mated parasitoids did not show any specific pattern (Tables 3).

TABLE 2. Preoviposition period, longevity, fecundity and the number of unspent eggs.

Status of female parasitoid	Preoviposition period (days) $\bar{X} \pm$ S.D. (Range)	Longevity (days) $\bar{X} \pm$ S.D. (Range)	* Fecundity $\bar{X} \pm$ S.D. (Range)	No. of mature unspent eggs $\bar{X} \pm$ S.D. (Range)
Mated (n=10)	6.2 ± 2.04 (4—9)	23.5 ± 5.3 (15—31)	74.3 ± 10.6 (59—91)	11.3 ± 8.0 (2—31)
Unmated (n=10)	9.5 ± 1.84 (6—12)	30.2 ± 9.2 (18—46)	50.2 ± 24.2 (11—86)	41.6 ± 26.8 (6—86)

Mean values in a column significantly different at $P=0.05$.

* Based on the no. of parasitoid larvae present in all the stung hosts, 5 days after exposure.

TABLE 3. The sequence in laying of male (M) or female (F) producing eggs* by mated *T. flavoorbitalis*.

Sequence of oviposition	No. of the replicate										
	1	2	3	4	5	6	7	8	9	10	
1	M	F	M	M	M	F	M	M	M	M	
2	M	F	M	M	M	M	M	M	M	M	
3	M	M	M	M	M	M	F	M	F	F	
4	M	M	M	M	M	M	M	F	F	M	
5	M	M	M	M	M	M	M	M	M	M	
6	M	M	M	M	M	F	F	M	M	M	
7	M	M	F	M	M	F	F	M	M	M	
8	M	M	M	F	M	M	M	M	M	F	
9	F	F	F	F	M	M	M	M	M	F	
10	M	M	M	M	F	F	F	M	F	F	
11	F	M	F	M	M	F	M	M	F	M	
12	M	F	F	M	F		M	F	F	F	
13	F	F		M	F		M	F		M	
14	F	M		M	F		M	M		M	
15	M	M		F	F		M	M			
16	M	F		F			F	F			
17	F	F		F			F	F			
18	F	M		F			F	F			
19		F		M				F			
20				F				F			
21				F							
22				F							
23				F							
Total No of eggs	18	19	12	23	15	11	18	20	12	14	162
Sex ratio (M:F)	2:1	1.4:1	2:1	1.3:1	2:1	1.2:1	1.6:1	1.5:1	1.4:1	1.8:1	1.6:1

* Based on the sex of the adult progeny.

Effect of single/multiple stinging:

Of the hundred host larvae that were subjected to just a single sting each, only 62 were parasitized with each of them containing a single parasitoid larva, when examined 5 days later.

Of the 100 larvae subjected to multiple stinging, each had been stung 8 times on an average (range 4–11) during the 30 min exposure, and contained 3–6 eggs (Table 4), when examined immediately after exposure.

Of the host larva multiple-stung for 30 min each and examined for parasitoid larvae 4 days after stinging, each host was found to contain 0–6 first instar parasitoid larvae (Table 5). Of the 100 hosts, a single host contained an exceptional number of 12 larvae. Seven of the exposed hosts remained unparasitized despite being subjected to multiple stinging.

Stung hosts in which later development of the parasitoid was followed (Table 6) contained 3–5, 1st instar larvae when examined 4–7 days after stinging. A single 2nd or 3rd instar parasitoid larva was found after the 8th day of parasitization. Around the 9th day of parasitization, a single 3rd instar larva was observed in the stung hosts. From each of the parasitized hosts left intact for 20 days, emerged a single adult parasitoid; except from 3 of the 30 hosts from which *L. orbonalis* emerged.

TABLE 4. The number of eggs laid in hosts* subjected to multiple stinging by *T. flavoorbitalis*.

Replicate	Number of insertions of the ovipositor	Total number of eggs laid
1	11	5
2	7	5
3	7	4
4	9	3
5	8	5
6	9	6
7	4	3
8	8	4
9	7	2
10	10	6
Mean ± S.D.	8 ± 1.9	4.3 ± 1.3

* Examined immediately after the 30 minute exposure to stinging.

DISCUSSION

The findings of this study on the reproductive biology of *T. flavoorbitalis* clearly suggest that mating shortens the preoviposition period significantly. Even though eggs were seen in the ovipositor of 5 day old females; both mated and unmated, oviposition commences much later in the unmated. Furthermore, mated females laid significantly more eggs than unmated females, in which most of the eggs remained unspent. But, whilst mating in *T. flavoorbitalis* favours early oviposition and is accompanied by a higher fecundity, it shortens the life span. Nevertheless, even with a longer life span unmated females failed to lay their full complements of eggs.

The fact that all the progeny of unmated *T. flavoorbitalis* are females make it a parthenogenetically thelytokous species. Mated females as usual, produced both male and female progeny. According to SLOBODCHIKOFF & DALY (1971) when in parthenogenetically thelytokous Hymenoptera the female is mated, the question of whether a given egg would be fertilized or not and thereby become a female or a male, depends on several factors. The absence of any

TABLE 5. Number of parasitoid larvae present in hosts* subjected to multiple stinging by *T. flavoorbitalis*.

Replicate	No. of hosts with parasitoid	No. of 1st instar larvae in each host replicate (1–10)										No. of parasitoid larvae/host $\bar{X} \pm$ S.D.
		1	2	3	4	5	6	7	8	9	10	
1	10	2	1	2	4	3	2	1	3	2	4	2.4 ± 1.1
2	9	3	0	2	2	3	12	1	4	0	1	2.8 ± 3.5
3	9	3	2	4	5	3	2	4	3	3	0	3.2 ± 0.9
4	9	3	2	3	1	0	2	3	3	1	2	2.0 ± 1.05
5	10	3	2	1	4	3	2	1	4	3	2	2.5 ± 1.1
6	10	2	1	3	3	2	1	3	1	2	2	2.0 ± 0.8
7	10	3	2	2	2	4	1	3	2	1	3	2.3 ± 0.9
8	9	2	2	1	3	2	6	0	4	2	1	2.3 ± 1.7
9	8	2	1	7	2	4	0	3	2	0	2	2.3 ± 2.1
10	9	2	2	3	1	2	0	2	2	1	3	1.8 ± 0.9
Mean ± S.D.	9.9 ± 0.32											2.36 ± 0.41

* When examined 4 days after exposure.
O– Unparasitized hosts (07%).

particular sequence in the laying of male and female producing eggs by mated *T. flavoorbitalis* females (Table 5), suggests the operation of such external factors. One such factor known to have an effect on sex determination in parthenogenetic species is the release of sperms from the spermatheca of the mated females. It appears that mated females of parthenogenetic parasitoids such as *T. flavoorbitalis*, has the ability to control the release of sperms from its spermatheca and thereby effect the fertilization of an egg moving down its oviduct. ABDELRAHAMAN (1974) working on *Aphytis melinus* (DeBach) (Hymenoptera: Chalcidoidae) and KUMARASINGHE (1984) working on *Evania appendigaster* (L) (Hymenoptera: Evaniidae) have observed similar phenomenon where some of the eggs laid by mated parthenogenetic females remained unfertilized.

The results of our studies on the behaviour of the parasitoid during oviposition imply that every insertion of the ovipositor into the body of the host does not necessarily lead to the laying of an egg. A single sting resulted in oviposition in only 62% of the larvae stung, while multiple stinging did not lead to any oviposition in 8.7% of the larvae. Nevertheless, multiple stinging is a frequent feature of the oviposition behaviour of *T. flavoorbitalis* as in most other parasitoids. Following such multiple ovipositions by *T. flavoorbitalis*, all the eggs laid in a host larva hatch into 1st instar

parasitoid larvae, which remain at this stage until the 7th day after oviposition. Thereafter, only one of these parasitoid larvae develops into its second instar, and eventually a single adult parasitoid emerges.

Earlier studies by BRADLEY & BURGESS (1934) on development of *T. flavoorbitalis* showed that the duration of the egg stage is 3.5 days, that of the 1st instar 5 days, and of the 2nd and 3rd instars respectively, 1 day each (at 80°F and 70% RH). SANDANAYAKE (1987) found durations of 4, 4, 2 and 2 days respectively for each of these developmental stages (at 28° ± 2°C). The results suggest that in *T. flavoorbitalis* despite the occurrence of multiple oviposition, fecundity can be assessed on the basis of either egg-counts (within 3 days of oviposition) or of larval counts (4–6 days after oviposition) when all the eggs laid had hatched into 1st instar larvae. Since the eggs of *T. flavoorbitalis* are fairly small (0.14 × 0.04 mm) and therefore difficult to detect within the host larvae, examination of hosts for 1st instar larvae would be easier and hence give more accurate results.

The emergence of a single parasitoid from a super-parasitized host suggests that

TABLE 6. Development of *T. flavoorbitalis* in *multiple stung hosts.

No. of insertions of the ovipositor/host $\bar{x} \pm$ S.D. (Range)	Time since oviposition (days)	Total no. of parasitoids hosts $\bar{x} \pm$ S.D. (Range)	State of parasitoid (no. of hosts with parasitoids)
7.4 ± 1.3 (6—9)	4	3.8 ± 1.7 (0—5)	1st instar (9)
7.4 ± 1.1 (6—9)	5	3.8 ± 1.1 (0—5)	1st instar (10)
8.4 ± 1.5 (6—10)	6	3.8 ± 1.5 (1—5)	1st instar (8)
8.2 ± 1.8 (6—10)	7	2.0 ± 1.4 (1—4)	1st instar (4) 2nd instar (5)
8.6 ± 1.5 (6—8)	8	1	3rd instar (10)
6.6 ± 0.9 (6—8)	9	1	3rd instar (10)
8.4 ± 1.2 (6—10)	10	1	3rd instar (8)
8.3 ± 1.4 (7—10)	20	1	adult (27)

* Over a period of 30 minutes.

multiple oviposition is a wasteful phenomenon in *T. flavoorbitalis*. That it occurs even when unparasitized host larvae are available (in our experiments) suggests that the parasitoid is unable to discriminate between parasitized and unparasitized host larvae. Pherhaps, this behaviour of *T. flavoorbitalis* is connected with the location of its host in nature (in long galleries) within the deeper tissues of the brinjal plant, *S. melongena*.

The all female progeny (thelytokous) of parthenogenetic *T. flavoorbitalis* could lead to a rapid build up of population and permit this parasitoid to keep close track of chnages in the population density of its host in the manner proposed by HASSEL (1978). Though this extrapolation is conjectural on our part, the possibility of rearing this parasitoid species in the laboratory on a large scale to provide large numbers of females for release in augmentative or inundative biological control programme is worth considering. Its relatively high fecundity, short life span, thelytokous parthenogenesis and the ease of rearing it in the laboratory, combined with certain other features of its biology referred to by SANDANAYAKE (1987), make *T. flavoorbitalis* a biocontrol agent of great potential in *L. orbonalis* infestations of brinjal.

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BIOLOGY AND HITHERTO UNKNOWN MORPHS OF *PROCIPHILUS (STAGONA) HIMALAYAENSIS* CHAKRABARTI (HOMOPTERA : APHIDIDAE)

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The alternation of *Prociphilus* (*Stagona*) *himalayaensis* between *Lonicera quinquelocularis* and *Pinus excelsa* has been confirmed through transfer experiments. Hitherto unknown morphs, i. e., fundatrix, alate emigrant and apterous sexules are reported and described. The biological activity of this species on these two host plants has also been discussed.

(*Key words*: *Prociphilus* (*Stagona*) *himalayaensis*, unknown morphs, transfer experiments, biology, western Himalayas)

INRODUCTION

Among aphids, Pemphigid species are one of the major gall forming group and mostly exhibit heteroecious holocyclic life and thus biologically interesting. In India, however, these species received very little attention with regard to their biology (Chakrabarti *et al.*, 1985; Chakrabarti, 1987). Chakrabarti (1976) described *Prociphilus* (*Stagona*) *himalayaensis* from two collections having apterous sexules and alate sexuparae from the roots of *Pinus excelsa* which is known as secondary host of this group of aphids.

The present study was concentrated to explore the primary host of this species and to discover the hitherto unknown morphs on this plant.

The aim of the present work was to explore the primary host, biological activity and to describe the hitherto not known morphs of *P.*(*S.*) *himalayaensis*. So far, alate sexuparae and apterous sexules were known (CHAKRABARTI, 1976). Here fundatrices and alate emigrants collected from leaf galls of *Lonicera quinquelocularis* and apterous oviparae collected from the laying of sexuparae in the Petridish, are described.

Males were not available and the only morph of this species remains yet to be described.

Abbreviations used : b.d. III = basal diameter of antennal segment III; p.t.= processus terminals; u.r.s = ultimate rostral segment; h.t.2 = second joint of hind tarsus; F.T.C. = first tarsal chaetotaxy.

Materials and method: Extensive field survey and careful field observation were made at various localities of western and northwest Himalaya where known primary hosts (i.e. *Cotoneaster* spp., *Lonicera* spp., *Syringa* spp. etc.) and secondary hosts (*Pinus* spp., *Taxus* spp.) of *Prociphilus* spp. are grown. *Prociphilus* species thus collected from these hosts were morphologically studied. Suspected *P.* (*S.*) *himalayaensis* samples were used in transfer experiments between *Lonicera quinquelocularis* and *Pinus excelsa*, and between *Lonicera quinquelocularis* and *Taxus*

baccata at Joshimath (*c* 1845 m), Garhwal range of western Himalaya during 1988 and 1989.

RESULT AND OBSERVATION

Only transfer between *Lonicera quinquelocularis* and *Pinus excelsa* were successful. After 30-45 min of release, the alates took shelter especially under loose bark and crevices and started to lay nymphs. These nymphs remain immovable for a while but started to move and ultimately settled along the side of resin excreted area of the roots. The behaviour of this developing stages was observed with the help of a hand lens.

After 1–2 days, some white areas having wax and woolly substances were noticed and colonies of apterous viviparae were developed there after 20–24 days. The whole colony was covered under a thick layer of wax and woolly substances, and as such difficult to locate different instars. The apterae were collected and studied morphologically. The microscopical study of this aphid material reveals a strong similarity with *P.* (*S*) *himalayaensis* Chakrabarti.

BIOLOGY :

This species is host-alternating one and alternates between *Lonicera quinquelocularis* (primary host) and *Pinus excelsa* (secondary host).

A. *On Primary host* : The species of *Prociphilus* are known to infest *Amelenchier*, *Cotoneaster*, *Crataegus*, *Fraxinus*, *Syringa* and *Lonicera* as primary host where they produce leaf galls and migrate to roots of coniferous plants as secondary host (Chakrabarti, 1987; Ghosh, 1984; Heie, 1980; Smith, 1969). *P.* (*S.*) *himalayaensis* in the area of present study utilises *Lonicera quinquelocularis* as primary host, where the following activities were observed.

i) *Spring phase* : This phase begins with the hatching (March–April) of overwintered eggs. The eggs laid in the cracks and crevices of bark are elongated oval in shape orange-yellowish in colour at an early stage but become blackish brown at later stage. The newly hatched nymphal fundatrices are blackish, settle on the ventral side of the leaf, and start to feed and grow. Their feeding activity results in leaf-pseudogalls which ultimately shelter the fundatrices. The fundatrix after maturation starts to lay nymphs which mature into alate emigrants in the month of April-May. These alatoid nymphs after maturation migrate to secondary host, the *Pinus excelsa* in May-June.

ii) *Autumn and winter* : With the onset of autumn (September–October), alate sexuparae become prevalent in the colony on the secondary host. These alates after maturation immigrate to primary host in prewinter months (November-December), where they settle on bark crevices of the old branches and start to lay nymphs which ultimately develop into sexules. The ovipara 1–2 days after mating lay only one egg. The eggs are attached to the substratum by wax threads at both ends. Sometimes, more than one egg are found as cluster to undergo overwintering. The egg laying behaviour was observed in the field laboratory under the dissecting microscope.

Gall formation : The feeding activity of nymphal fundatrices on the ventral surface of sprouting leaves results in curling the leaf dorsally, and thus a small tubular leaf-pseudogall is produced which may be termed as 'primary gall'. These galls are found mostly at the very basal part of leaf-lamina. The alatoid nymphs laid by fundatrix leave the primary gall in batches either due to overcrowding or due to the old age of the leaves and start feeding on the apical younger leaves produced very recently. Here, they induce

galls, the 'secondary gall'. However, a dimorphism in secondary gall position was also observed. The secondary galls produced by the early generation of nymphs are elongated tube-like formed by the folding of marginal part of leaf lamina. The second type of secondary gall is a complete folding of leaf and looks like a spiral and found mostly at the very apical part of infested twigs.

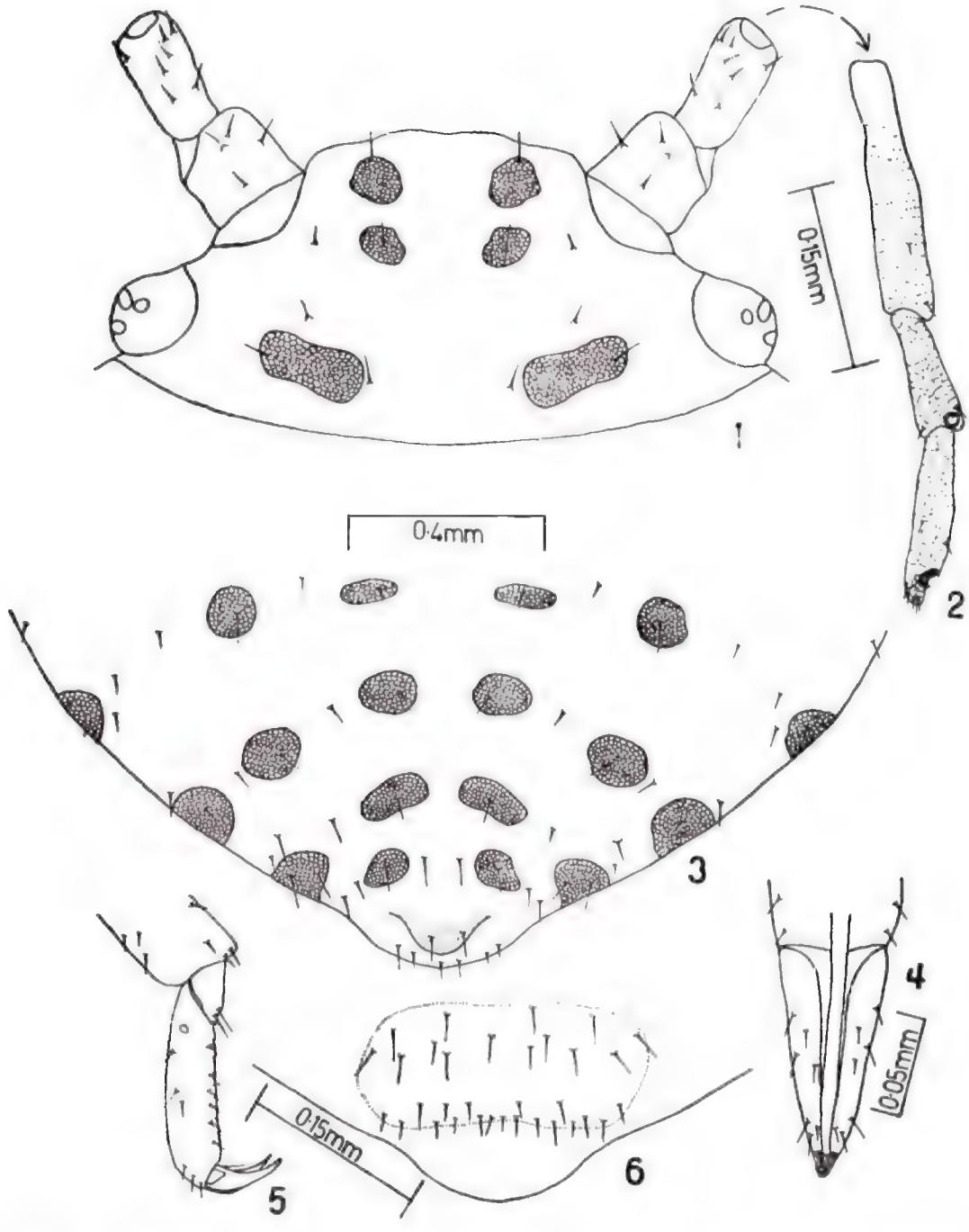
B. *Secondary host* : As mentioned earlier, coniferous plants constitute the major secondary host of this group of aphids. In India, especially in the area of study, *Pinus excelsa* serves as the secondary host of this aphid species. Alate emigrants, after settling on the exposed roots of *Pinus excelsa* (May-June) start to lay the nymphs (3rd generation) which after maturation (July-August) start the next apterous exules generation (4th generation). These colonies remain covered fully under the waxy substances and honey dews secreted by the aphid himself. In autumn (September-October), sexuparous generation (5th generation) appear in the colony, which in the prewinter months (November-December) finally immigrate to the primary host.

SYSTEMATIC ACCOUNT :

Fundatrix (Figs. 1–6) : Body elongated oval, 2.24–3.26 mm long and 1.95–2.60 mm as maximum width, pale brown in colour except head, antennae, legs and genital plate which are deep brown. Head fused with pronotum, with an indistinct suture; dorsum with 6 large wax gland plates and with 10–12 long and finely pointed hairs, longest one on vertex 26–33 μm long. Antennae 5-segmented, 0.19–0.25 times the body, smooth except segment III which is gradually spinularly imbricated apicad, segment I as long as width with 4–5 hairs, segment II longer than wide with 6–9 hairs; p.t. 0.014–0.026 mm long and 0.16–0.21 times the base of the segment; primary rhinaria ciliated and surrounded by ciliated accessary rhinaria; flagellar hairs long, finely pointed and sparsely located, longest one on segment III 14–23 μm long and 0.46–0.77 times the b.d. III. Rostrum reaches beyond the fore-coxae. U.r.s. 0.63–0.69 times the h.t.2 and with 6–10 accessary hairs. Thorax smooth, prothorax with paired marginal and spinal wax gland plates, meso- and meta-thorax with paired marginal pleural and spinal wax gland plates. Abdominal dorsum membranous and smooth, tergites 1–6 each with paired marginal, pleural and spinal wax gland plates, tergite 7 with paired marginal and spinal, and 8th with paired spinopleural wax gland plates, wax galnd plates are oval to elongated oval in shape, boardered by a continuous chitinous rim, except those on 8th tergite, was cells are pentagonal to hexagonal in shape and leaving no intercellular space; dorsal hairs long and pointed, tergites 7 and 8 with 12-14 and 8–12 hairs respectively; longest hairs on anterior tergite 23–26μm long and 0.55–0.92 times the b.d.III and those on tergites 7 and 8 30–35 μm long and 0.81–1.16 times the b.d.III. Siphunculi absent. Cauda small, half circular, with 2 long hairs. Venter smooth except genital plates which is with some spinules; ventral hairs shorter and more numerous than dorsal hairs; genital plate with 14–19 hairs on anterior margin and 18–26 hairs on posterior margin; anal plate with 20–31 hairs. Legs smooth, F.T.C. 3,2,2.

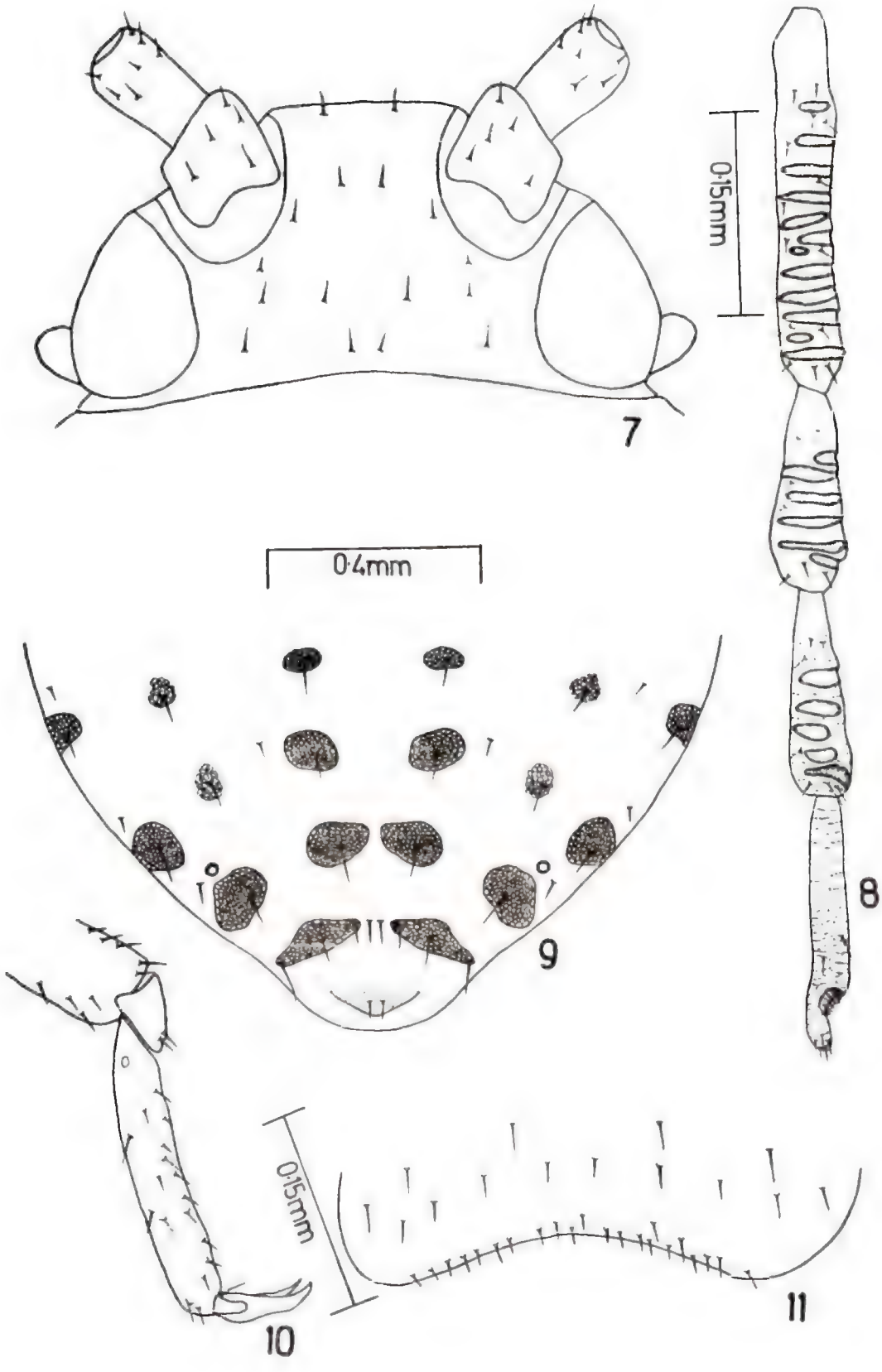
Measurements of one specimen in mm: Body length 3.26, width 2.6; antenna 0.63; antennal segments III: IV: V 0. 56: 0.37; 21: 0. u. r. s. 0.11, h.t. 2 0.16.

Alate emigrant (Figs. 7–11): Body elongated 2.35–2.94 mm in length and 0.88–1.0 mm as maximum width. Head dorsum with 14—18 long and pointed hairs, paired posterior spinal hairs on elevated rugose sockets, longest hair on vertex 30–35 μm long and 0.86–1.07 times the b.d.III. Antennae



Figs. 1–6. *Prociphilus* (*Stagona*) *himalayaensis* Chakrabarti, apterous fundatrix,. 1. dorsum of head; 2. antennal segments III–V; 3. posterior portion of abdomen; 4. ultimate rostral segment; 5. hind tarsal segment; 6. genital plate.

Figs. 7–11. (P. 173) *Prociphilus* (*Stagona*) *himalayaensis* Chakrabarti. alate emigrant. 7. dorsum of head; 8. antennal segments III–VI; 9. posterior portion of abdomen; 10. hind tarsal segments; 11. gential plate.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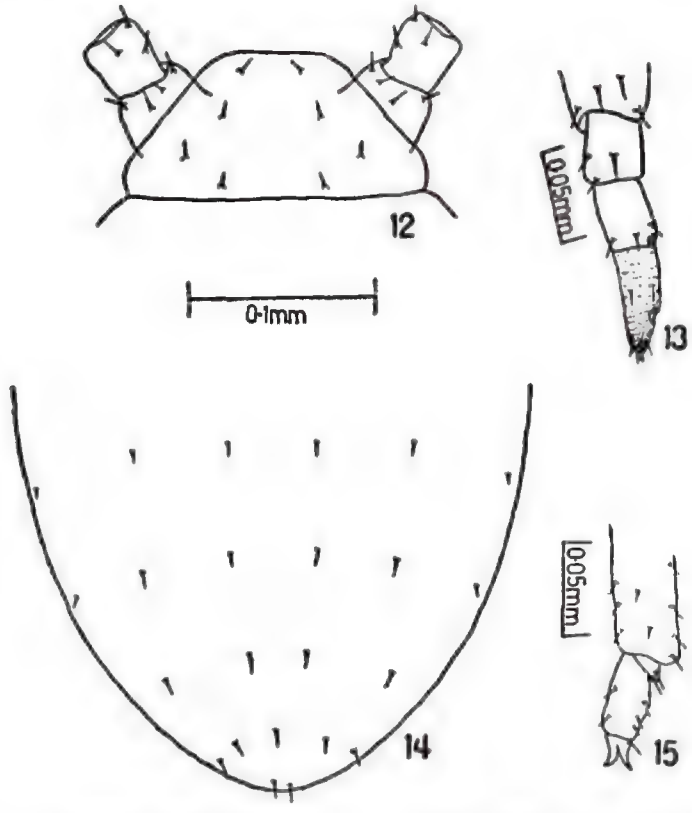
6–segmented, smooth except segment V which is spinularly imbricated apicad, 0.13–0.19 times the body, segments I and II with 5–7 and 6–9 hairs respectively; segments III, IV and V with 10–15, 4–7 and 4–6 narrow and weekly ciliated secondary rhinaraia encircling the half diameter of the segment; p.t. 0.02–0.03 mm long and 0.13–0.19 times the base of the segment, primary rhinaria small and densely ciliated; flagellar hairs long, pointed and sparsely located, longest one on segment III 14–18 μm long and 0.40–0.53 times the b.d. III. U.r.s. 0.40–0.46 times the h.t.2, with 6–8 accessary hairs. Thorax deep brown, metathorax with a paired spinal wax gland plates. Abdominal dorsum membranous, pale brown, tergites 1–7 with paired spinal and marginal wax gland plates, with paired pleural one on tergites 3–6 which are hardly discernible, tergite 8 with a paired large wax gland plate, wax cells are oval with thick wall thus sometimes leaving few intercellular spaces; dorsal hairs long, thick and finely pointed longest one on anterior tergites 30–35 μm long and 0.87–1.0 times the b.d. III; tergites 7 and 8 with 6–8 and 8–10 long hairs respectively, longest one on these tergites 37–47 μm long and 1.2-1.4 times the b.d.III respectively. Siphunculi small ring–like and hardly discernible. Cauda brownish with 2 hairs. Venter faintly spinular; ventral hairs as the dorsal hairs. Genital plate brown with 12–18 hairs on the anteiror margin and 14–24 hairs on the posterior margin. Gonapophyses three, each with 14–20 hairs. Legs deep–brown and smooth; F.T.C.2,2,2. Other characters as in the fundatrix adult.

Measurements of one specimen in mm: Body length 2.73, width 1.4; antenna 1.03 antennal segments III: IV:V:VI 0.33: 0.17: 0.16: (0.17 .0+03): u.r.s 0.10; h. t.2 0.24.

Apterous oviparae (Figs. 12–15) : Body elongated oval, 0.67–0.90 mm in length and 0.35 mm as maximum width, membranous except legs which are more chitinous. Head dorsum with 8 long, thick and pointed hairs originate from a developed socket, 14 μm long. Antenna 4-segmented, segment III with an abortive division, 0. 16–0 .19 mm long and 0.19–0.22 times the body, smooth except ultimate segment which is with some spinules; p.t. 0.014–0.016 mm long and 0.35–0.40 times the base of the segment; primary rhinaria weakly ciliated; segments I and II with 4 and 3 hairs respectively. Thorax smooth, each thoracic segment with 2 pairs of hairs. Abdominal dorsum smooth, without wax gland plates, dorsal hairs long, thick with acute to accuminate apices; tergite 7 with 4 hairs, which increases in length cauded; tergite 8 with 5 hairs, longest hair on tergites 7th and 8th 26 μm long. Cauda with 2 hairs. Siphunculi absent. Venter faintly spinulose, ventral hairs shorter than dorsal hairs; anal plate with 5 hairs. Legs smooth, hind tibiae 0.11—0.15 times the body. F.T.C. 3,3,2.

Measurements of one specimen in mm: Body length 0.88, width 0.36; antenna 0.19, antennal segments I:II:III:IV 0.3:0.03:0 .06: (0.05+0.02); h.t.2 0.06.

Apterous sexule : Chakrabarti (1976) while describing the species mentioned only the marginal wax gland plates on abdominal tergites 1–7 and single spinal plate on tergite 8. Re-examination of the type materials and some additional materials of this species also exhibit paired pleural and spinal wax gland plates on tergites 1–6 and paired spinal wax gland plates on tergite 7 in addition to wax gland plates described by Chakrabarti (1976) stated above.



Figs. 12–15 *Prociphilus* (*Stagona*) *himalyaensis*. apterous ovipara. 12. dorsum of head; 13. antenna; 14. posterior portion of abdomen; 15. hind tarsal segments.

Materials examined: 6 apterous exules, 15 alate sexuparae and many alatoid nymphs, INDIA : HIMACHAL PRADESH, Tolash, 30.x.1970 (Coll.A.N. Chowdhuri) from *Pinus wallichiana* (Holotype and Paratypes); 2 apterous fundatrices, UTTAR PRADESH, Garhwal, Joshimath, 22.iv.1984 (coll.D. Ghosh); 6 apterous fundatrices, Kumaon, Rari, 6.v.1986 (coll.N. Debnath); 1 apterous fundatrix, Joshimath, 15.v.1989; 2 apterous fundatrices, Bhyunder, 29.v.1989; 16 alate emigrants, Joshimath, 15.v.1989; 4 alate emigrants, 19.v.1989; 12 alate emigrants, 25.v. 1989 from *Lonicera quinquelocularis*; 3 apterous exules and 2 nymphs, Joshimath, 15.vi.1989; 4 apterous exules, 19.vi.1989; 3 alate sexuparae,3 .xi.1989; 3 alate sexuparae, 10.xi.1989 from *Pinus excelsa*; 4 apterous oviparae deposited), 11.xi.1989 (coll. P. K. Banerjee).

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OVIPOSITIONAL BEHAVIOUR AND ECLOSION OF EGGS OF *HELICOVERPA ARMIGERA* AS AFFECTED BY INSECTICIDES

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Ten insecticides were evaluated for their ovicidal effect against eggs of the cotton bollworm, *Helicoverpa armigera* following dipping and spraying methods. The maximum ovicidal activity against *H. armigera* by dipping and spraying methods were recorded with methomyl, triazophos and thiodicarb. The maximum ovipositional repellent property on treated fruits were recorded with cartap hydrochloride, triazophos and thiodicarb. It is concluded that for practical purposes, spraying is a more accurate method for evaluating ovicidal activity of an insecticide.

(*Key words : Helicoverpa armigera* control, ovicidal activity)

INTRODUCTION

The cotton bollworm, *Helicoverpa armigera* (Hubner) has always been a major pest on crops particularly pulses, cotton and vegetables. KAUSHIK et al. (1969) estimated 41–56% loss in cotton in Madhya Pradesh. In horticultural crops such as tomato, yield losses of 40–50% are reported in Tamil Nadu (SRINIVASAN, 1959). In 1982, *Helicoverpa armigera* caused loss estimated at Rs 300 crores to pulses (KING, 1988). Recently it has been a serious threat to cotton cultivation in several districts of Andhra Pradesh.

The egg stage, by virtue of its extreme diversity in terms of location, seasonal occurrence, incubation period, and physiological susceptibility, offers tremendous scope for the development of programmes for its control. The ovicidal activity of several insecticides have been evaluated against eggs of various insect pests. However, it has been observed that variations in ovicidal activity occurs with the methodology adopted for the experiment. Hence in the present investigation the ovicidal activity of several insecticides to *H. armigera* following two common methods, viz., dipping and spray method were compared to study the extent of variation in the results obtained between the two methods. The influence of age of egg on susceptibility and also the influence of these insecticides on oviposition were also studied.

MATERIAL AND METHODS

Aqueous solution of the various insecticide concentrations were prepared in 100 ml beakers. A minimum of 25 eggs were used for each repliction and each experiment was replicated three times. The ten insecticides selected for the present study were: methomyl (Lannate L 25 @ 0.048 %); triazophos (Hostathion 40 EC @ 0.08%); endosulfan (Endocel 35 EC @ 0.07%); cypermethrin (Cyperkill 25 EC @ 0.05%); ethofenprox (Trebon 10 EC @ 0.02%); cartap hydrochloride (Padan 50 SP @ 0.1%); flufenoxuron (Cascade 10 WDC @ 0.01%); thiodicarb (Larvin 375 F @ 0.75%); chlorpyrifos (Coroban 20 EC @ 0.04%); and quinalphos (Ekalux 25 EC @ 0.05%). An untreated check was also kept.

The freshly laid 0 to 1, 1 to 2 and 2 to 3 day old eggs of *H. armigera* were dipped into the insecticidal solutions for 15 seconds and allowed to dry. Dipping in water served as control. The number of hatched and unhatched eggs were recorded and the egg mortality and hatchability percentgage were also worked out for different treatments.

Similarly, eggs were sprayed with various insecticides using a Potter's tower. Solution of each insecticide (1 ml) was sprayed on a Petridish containing eggs with the help of Potter's tower at a constant air pressure. The untreated control was sprayed with water. After spraying the eggs were kept 30 minutes for drying and observation on hatchability were recorded.

To study influence on oviposition, freshly emerged male and female moths were exposed to okra fruits dipped in various concentrations of the ten insecticides. Untreated fruits were used for the control. The number of eggs deposited by the moths were recorded and from these eggs, percent hatchability was also recorded. The data obtained from the various experiments were converted into percentage mortality, corrected using ABBOTT's (1925) formula, transformed (Arc-sine values) and then subjected to analysis of variance.

RESULTS AND DISCUSSION

The ovicidal activity of several insecticides against *H. armigera* following dipping and spraying method are furnished in Table 1.

The results obtained by dipping method revealed that methomyl, triazophos, thiodicarb, chlorpyrifos and quinalphos exhibited high ovicidal activity against all three stages of *H. armigera* eggs. Complete inhibition of hatching was recorded with the above insecticides. The age of the egg did not have any influence on the susceptibility of the eggs with methomyl, triazophos and quinalphos. By spraying under Potter's tower the superior ovicidal activity of methomyl, triazophos and chlorpyrifos was confirmed although the levels of egg mortality obtained by this method was much lower than by dipping method. VEKARIA & VYAS (1985) recorded 78.44 percent mortality with cypermethrin, while in the present studies it was found to cause only 54.32 percent inhibition to hatching.

The same authors reported 70.10 percent mortality for quinalphos which is in close conformity with the present study. However, for chlorpyrifos only 26.31 percent mortality was recorded while in the present study, it was 74.71 percent and its ovicidal effectiveness is confirmed from the dipping method. PATEL & PATEL (1989) reported 100 percent mortality of eggs when treated with quinalphos and 90.90 percent mortality with cypermethrin.

The age of *H. armigera* eggs influenced its susceptibility to all insecticides including methomyl, triazophos, chlorpyrifos and quinalphos. The susceptibility of an egg to an insecticide may change during its embryonic development, and the relationship between age of egg and susceptibility may differ with both the insecticides and the species (SALKELD & POTTER, 1953).

The influence of the ten insecticides on oviposition by the gravid females on freshly treated fruits and one day after treatment were studied. The study indicated that the maximum reduction in egg laying was recorded in fresh okra fruits treated with cartap (83.61%) followed by triazophos (80.02%), ethofenprox (79.89%) and thiodicarb (78.16%) (Table 2). While recording the hatching of eggs laid in the various treatments it was observed that 100 percent inhibition

of hatching was recorded in methomyl, triazophos, endosulfan, cypermethrin, ethofenprox, thiodicarb, chlorpyrifos and quinalphos. On one day old treated fruits the least number of eggs were laid in cypermethrin and the highest mortality of eggs laid on treated fruits were recorded in methomyl (83.80%) and endosulfan (90.51%). This has a special significance under field conditions to determine the effect of spray residues on oviposition by gravid females and subsequent hatching of the eggs laid on such fruits.

It is concluded from the above experiments that spraying method is a more authentic and practical approach to detect the ovicidal activity of insecticides. The result obtained from the dipping method can be exaggerated estimates and quite often different from the practical situation.

TABLE 1. Ovicidal activity of insecticides to *H. armigera*.

sl. no.	chemicals		dipping method (% corrected mortality)*			spraying method (% corrected mortality)*		
			0—1	1—2	2—3	0—1	1—2	2—3
1.	methomyl	0.048 %	100 (90.00)^{a}	100 (90.00^{a}	100 (90.00)^{a}	78.61 (62.61)^{a}	62.67 (52.32)^{a}	55.47 (48.15)^{a}
2.	triazophos	0.08 %	100 (90.00)^{a}	100 (90.00)^{a}	100 (90.00)^{a}	73.08 (58.75)^{a}	55.84 (48.36)^{b}	38.58 (38.15)^{a}
3.	endosulfan	0.07 %	85.20 (65.94)^{b}	69.12 (56.35)^{e}	56.41 (48.69)^{de}	50.44 (45.25)^{be}	42.11 (40.39)^{d}	35.10 (36.28)^{ab}
4.	cypermethrin	0.05 %	100 (90.00)^{a}	75.97 (60.73)^{e}	63.34 (52.84)^{cd}	54.32 (47.49)^{b}	44.11 (41.60)^{cd}	44.10 (39.87)^{a}
5.	ethofenprox	0.02 %	82.94 (65.94)^{b}	73.82 (59.26)^{e}	70.45 (57.29)^{e}	54.69 (47.70)^{b}	50.15 (45.38)^{be}	7.76 (15.82)^{e}
6.	cartap	0.10 %	100 (90.00)^{a}	61.14 (51.48)^{d}	46.89 (43.17)^{ef}	29.99 (32.92)^{d}	15.18 (22.67)^{f}	12.73 (20.35)^{e}
7.	flufenoxuron	0.01 %	100 (90.00)^{a}	86.35 (68.49)^{b}	41.52 (40.05)^{f}	9.35 (17.46)^{d}	8.44 (16.42)^{g}	4.38 (16.50)^{e}
8.	thiodicarb	0.75 %	100 (90.00)^{a}	100 (90.00)^{a}	92.70 (74.54)^{b}	41.91 (40.33)^{e}	33.06 (35.67)^{e}	16.12 (23.55)^{be}
9.	chlorpyrifos	0.04 %	100 (90.00)^{a}	100 (90.00)^{a}	96.44 (72.33)^{b}	74.17 (59.50)^{a}	60.28 (49.01)^{ab}	45.36 (42.30)^{a}
10.	quinalphos	0.05 %	100 (90.00)^{a}	100 (90.00)^{a}	100 (90.00)^{a}	60.24 (50.95)^{b}	46.28 (42.86)^{cd}	44.20 (41.65)^{a}
	CD (at $P=0.05$)		2.72	4.67	6.31	5.27	3.78	14.31

Figures in parenthesis are arc-sine transformed values.

* Mean of three replications.

Means with the same letters are not significantly different at 5% level by DMRT.

TABLE 2. Ovipositional repellent property of insecticides to *H. armigera*.

sl. no.	chemicals		0 DRT		1 DRT	
			% reduction in egg laying*	corrected % mortality of eggs laid *	% reduction in egg laying *	corrected % mortality of eggs laid
1.	methomyl	0.048 %	54.84 (48.09)^{cd}	100 (90.00)^{a}	31.48 (33.59)^{d}	93.80 (75.67)^{a}
2.	triazophos	0.08 %	80.02 (63.97)^{ab}	100 (90.00)^{a}	61.14 (51.69)^{ab}	65.62 (54.34)^{b}
3.	endosulfan	0.07 %	52.75 (46.75)^{d}	100 (90.00)^{a}	37.83 (37.59)^{cd}	90.51 (72.55)^{a}
4.	cypermethrin	0.05 %	74.27 (60.70)^{abc}	100 (90.00)^{a}	75.33 (60.77)^{a}	56.84 (48.97)^{bc}
5.	ethofenprox	0.02 %	79.89 (64.40)^{ab}	100 (90.00)^{a}	59.37 (50.46)^{abc}	56.09 (48.51)^{bc}
6.	cartap	0.10 %	83.61 (66.44)^{a}	71.28 (58.31)^{b}	66.30 (54.42)^{ab}	43.77 (40.75)^{c}
7.	flufenoxuron	0.01 %	61.17 (51.78)^{bcd}	64.04 (53.80)^{b}	35.85 (36.54)^{cd}	50.43 (45.27)^{c}
8.	thiodicarb	0.75 %	78.16 (62.26)^{ab}	100 (90.00)^{a}	41.68 (43.78)^{bcd}	72.47 (58.85)^{b}
9.	chlorpyrifos	0.04 %	68.26 (56.62)^{abcd}	100 (90.00)^{a}	58.27 (49.94)^{abc}	63.81 (53.21)^{b}
10.	quinalphos	0.05 %	63.82 (53.34)^{bcd}	100 (90.00)^{a}	45.34 (41.87)^{bcd}	65.67 (54.25)^{b}
	CD (at $P=0.05$)		12.652	8.40	14.65	11.89

DAT – Days After Treatment.

Figures in parenthesis are arc-sine transformed values.

* Mean of three replications.

Means with the same letters are not significantly different at 5% level by DMRT.

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STUDIES ON THE CHALCIDID PUPAL PARASITOIDS OF THE COCONUT CATERPILLAR *OPISINA ARENOSELLA* WALKER IN KERALA, INDIA

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The coconut caterpillar *Opisina arenosella* Walker has a *Brachymeria* - dominated parasitoid community in Kerala, among which *Brachymeria nosatoi* Habu is the most important species, followed by *B. nephantidis* Gahan. The females of *B. nosatoi*, *B. nephantidis*, *B. atteviae* Joseph *et al.*, *B. lasus* (Walker) and *Antrocephalus hakonensis* (Ashm.) are monandrous, but their males are polygynous. *B. nosatoi* possesses the essential attributes of an effective biocontrol agent. It adheres to rigid selection of males and elaborate courtship, provides higher percentage parasitism, breeds well in summer months and prolonged drought conditions and disperses uniformly in pest-infested coconut gardens. However, at present it dominates over the south Kerala tracts only.

The males of *Brachymeria*, during courtship, press the wings and abdomen of the female with their antennae from the rear, while *A. hakonensis* mounts on the female to have an antennal to antennal contact. *B. nosatoi* presses the wings (and abdomen), slightly rubs on the wings upwards, rocks the female and inseminates without jerking. *B. nephantidis* presses the wings only and inseminates with jerking. *B. lasus* places the antennae over the wings, applies more downward pressure at frequent intervals, rocks the female, slightly rubs downwards and mates without jerking. *B. atteviae* rubs the wings down and up, rocks and mates with jerking.

Mating in *Brachymeria* spp. lasts 4–12 seconds. *A. hakonensis* does not select males. Courtship is also simple and it mates with jerking, for 25 to 35 seconds. The life cycles of four species of *Brachymeria* are almost identical and completed in 12 to 20 days. Their adults survive to parasitise 2 to 3 generations of the pest. *A. hakonensis* has a longer life cycle of 16 to 23 days.

(*Key words*: *Brachymeria* spp., *Antrocephalus*, courtship behaviour, life cycle, biological suppression, *Opisina arenosella*)

INTRODUCTION

The parasitoid community of *Opisina arenosella* Walker (Lepidoptera: Oecophoridae) on coconut is unique in that it is dominated by *Brachymeria* spp. Seven species of them *B. nosatoi* Habu., *B. nephantidis* Gahan, *B. atteviae* JOSEPH, NARENDRAN & JOY (*B. hime atteviae* JOSEPH *et al.*), *B. lasus* (Walker), *B. euploeae* (Westw.) *B. excarinata* Gahan (JOSEPH *et al.*, 1973) and *B. megaspila* Cameron (PILLAI & NAIR, 1986b) parasitise the pupae of *O. arenosella* in Kerala. Among them, *B. nosatoi* is the most important one followed by *B. nephantidis* (JOY & JOSEPH, 1977a: PILLAI & NAIR, 1981). Three species of *Antrocephalus* are listed by NARENDRAN (1985) as pupal parasitoids of *O. arenosella*. They are *A. hakonensis* (Ashm.), *A. carinicеps* (Cam.) and *A. phaeospilus* Waterston. Among them, *A. hakonensis* is more common,

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even though all of them play only an insignificant role in the natural suppression of *O. arenosella*. Excepting *B. nosatoi* and *B. nephantidis*, other species of *Brachymeria* are rather unimportant, when their role in the biological suppression of the pest is taken into account. However, *B. excarinate* is a dominant parasitoid of the coleopteran, *Calopepla leayana* Latr. on the forest tree *Gmelina arborea* in Kerala (MOHANDAS, 1986).

A good deal of work on *Brachymeria* spp. had already been done by JOY & JOSEPH (1972, 1973, 1977a, 1977b), JOSEPH et al. (1973); JOY *et al.* (1978); NARENDRAN & JOSEPH (1975, 1976a); PILLAI & NAIR (1981, 1982a, 1982b) and SATPATHY & RAO (1972). According to PILLAI & NAIR (1982b) 52.3% of pupae of *O. arenosella* are suppressed by the pupal parasitoids, of which *Brachymeria* spp. claimed 49%, the share of *B. nosatoi* was 30.1%, *B. nephantidis* 15.7%, *B. lasus* 1.3%, *B. atteviae* 1.3%, *Trichospilus pupivorus* Ferr. 2.6%, *Xanthopimpla punctata* F. 0.7% and *Eurytoma albotibialis* Ashmead (hyperparasitoid) killed 0.7% population of *Brachymeria* spp. In this paper, the courtship and mating behaviours and life history of *B. atteviae* and courtship and mating behaviours of *B. nephantidis* are presented for the first time. Additional information collected on *B. nosatoi, B. nephantidis, B. lasus* and *A. hakonensis* and the salient features of *Brachymeria* spp. are also furnished.

MATERIALS AND METHODS

Courtship and mating behaviours of parasitoids were studied under a stereoscopic binocular microscope in the laboratory. The parasitoids were reared in the laboratory using the method described by PILLAI & NAIR (1982a). Pupae of *O. arenosella* remaining within the cocoons inside the silken galleries were exposed for oviposition to *B. nosatoi* and the pupae with or without cocoons (excised) to the other species of parasitoids.

About 50 adults of *B. nosatoi* comprising both sexes are released in a clean, dry cylindrical glass jar, 17.5 cm long and 6.75 cm wide, inside which 12 cm long and 6.25 cm wide cardboard piece is inserted to facilitate the parasitoids to move and rest. The mouth of the jar is closed with a piece of muslin cloth tightened with rubber bands. The bottle is kept horizontally. The parasitoids are transferred to fresh clean bottle in every 4 to 5 days. For studies on longevity of adult parasitoids, undiluted honey was provided as minute droplets on wax-coated paper continuously.

RESULTS

Salient features of Brachymeria spp.:

Under similar conditions of temperature and relative humidity, the life cycle of *B. nosatoi, B. nephantidis, B. atteviae* and *B. lasus* are almost identical. During courtship, the female parasitoid keeps her wings folded on the abdomn. Standing behind in a straight line with the female the male keeps the entire length of his anteriorly projected antennae over the middle of the female's wings covering the base to tip of the abdomen and applies pressure. The front part of the head of the male is also pressed against the tip of the wings of the female.

There is selection of males is varying degrees. The courting male should be able to apply a certain amount of pressure on the wing and abdomen of female with the antennae, which are either held closely (*B. nosatoi*, *B. nephantidis* and *B. atteviae*) or held apart is in *B. lasus*, the limit of which appears to vary in each species and the male which applies the required amount of pressure is allowed to mate. Courtship is elaborate and selection of males is rigid in *B. nosatoi*.

Insemination is quick in *Brachymeria*. It takes only 4–12 seconds and they mate with jerking or without jerking.

Females are monandrous and the males polygynous. Host feeding is present in all species to a lesser extent. Adults are very sturdy and they survive to parasitise 2 or 3 generations of the pest. All of them are amenable to laboratory multiplication. All are affected by the hyperparasitoid *Eurytoma albotibialis* Ashm. (PILLAI & NAIR, 1985). With the exception of *B. nasatoi* all others make holes in the cocoon of the host pupa for oviposition. Disorganisation of host tissues prior to oviposition is absent with the exception of *B. nosatoi*. Superparasitism in the laboratory and multiparasitism in the field are quite common among them. Sex-ratio is favourable to female progeny. With the exception of *B. nosatoi*, others have hyperparasitic tendency as well.

Brachymeria nosatoi Habu

JOY & JOSEPH (1972) reported *B. nosatoi* for the first time from Kerala, India. It is distributed in Japan, Sri Lanka (COCK & PERERA, 1987) Lacs, the Philippines, India and New Guinea and its hosts include the cotton pink boll worm, *Pectinophora gossypiella* (Sound.), *Dioryctria splendidella* H., *Evetria cristata* W., (NARENDRAN & JOSEPH, 1975) *Conogethes* (*Dichocrocis*) *punctiferalis* (Guen.) and *Hapalia machaeralis* (Wlk.). Although oligophagous, its main host is *O. arenosella* and it breeds with perfect synchrony with this host. MOHAMED *et al.* (1982) briefly discussed its life history and mating behaviour.

B. nosatoi dominates most other pupal parasitoids of *O. arenosella*, except *Xanthopimpla punctata* F. and *X. nana nana* Schulz. in South Kerala. When simultaneous multiparasitism occurs with other *Brachymeria* spp. and *A. hakonesis*, *B. nosatoi* emerges successfully. It has high searching and dispersal capacity. It parasitises *O. arenosella* throughout the year and provides over 30% natural parasitism. It parasitises pupae with big cocoons (without making holes) and it also oviposits in pupae through the leaf (JOY & JOSEPH, 1977b).

Responding to the rapid increase of population of *O. arenosella* it also numerically increases its population, especially during summer months. It can withstand prolonged drought, high summer temperatures and low humid conditions. There was an unprecedented drought during August, 1982 to June, 1983 in Kerala. Eventhough all other pupal parasitoids were affected by drought, *B. nosatoi* was not at all affected and nearly 90% of *Brachymeria* emerged from the field-collected pupae during April to August, 1983 were *B. nosatoi*. There is no hyperparasitic tendency in *B. nosatoi*.

In days of continuous rain, especially morning hours, mating is difficult, thereby the male population increases in the field for a short period. Mating and oviposition are also rare in sultry weather conditions (JOY & JOSEPH, 1977b).

Courtship and mating:

Females usually mate in 1 to 3 days of emergence, with the earlier emerged males. Sunlight stimulates sexual activity in both the sexes. Courtship is generally long and eloborate and selection of male is very rigid. Many males usually court a female before mating occurs. The following steps lead to successful mating.

1. On recognition of the virigin female, the sexually stimulated male sways the front part of the body and establishes antennal to wing and abdominal contact with her from the rear. The female usually does not stop, kicks the male

and moves away, so the male exhibits the following courtship behaviour to make the female receptive;

a. Makes clockwise and anticlockwise swaying movements around the female in quarter, semi or full circles.

b. The male may come face to face with the female and pats on the head with the antennae, fans his wings and moves his abdomen up and down.

c. It may tap or press at the thorax of the female, standing at a 99° angle.

d. The male mounts the female from the front proceeds to the rear to dismount, takes up the usual courtship position behind the female and presses the wings.

2. When one male courts a female, it will stand behind the female in a straight line and place the closely held and anteriorly projected antennae on the middle of the abdomen over the wings and apply pressure. But, when two males court at a time, deviating from the abovementioned position, both males stand on either side of the female in 45° angles and press the wings.

3. When many males try to court a female they assemble one behind the other, the first male presses the wings of the female and others press the wings of the male just in front of it. This indicates the presence of a strong sex pheromone in tne virgin female of *B. nosatoi*, which guides the male in courtship and mating. When the female parasitoid moves, all the courting males also follow her in a line just like the bogies of a moving train. Courtship often exceeds half an hour.

4. While pressing the wings, it also rocks the female. Under the stereoscopic microscope, slight upward rubbing of the antennae over the wings, on the same place, could also be observed. Male lowers and raises his abdomen occasionally.

5. The male in courtship also kicks other intruding males.

6. He soon becomes excited, stands tall on the tarsus of the meso - and metathoracic legs and applies as much pressure as he can apply.

7. If the female is satisfied that the male is sutiable, she widens her legs, raises the abdomen and exposes the genital pocket. The male stops wing pressing, moves forward to hold her with all his legs and mates without jerking for 8 to 10 seconds. The mated female may allow other males to court subsequently, but never mates for a second time.

Oviposition:

When host pupae are offered along with the cocoons, after standing over them, the female parasitoids insert their ovipositor directly into the thoracic region of the host pupae, lacerate the internal tissues, with 40 to 50 ovipositor thrusts at a stretch, and lay eggs in them. When several females are present in the rearing jar, upto 23 eggs are found laid in a host pupa. As superparasitism is common in the laboratory, host pupae should be exposed only for four to six hours. The points of insertions become black in two days after oviposition, by which the parasitised and unparasitised pupae can be separated. Five to six days after oviposition, the abdominal segments enlarge and become darker.

Herculia nigrivitta (Walker) infesting dry leaves of coconut was recorded as a new host of *B. nosatoi*, but this appeared to be an insignificant host.

The life histories of *B. nosatoi, B. nephantidis* and *B. atteviae* are presented in Table 1.

Brachymeria nephantidis Gahan

This is the second important pupal parasitoid of *O. arenosella*. Unlike *B. nosatoi*, it is widely distributed in Kerala and other parts of India. In North Kerala region, *B. nephantidis* provides higher percentage parasitism than that of *B. nosatoi* (JOY & JOSEPH, 1977a). In some localities of south Kerala it may also provide higher parasitism than that by *B. nosatoi* for a short period. However, average parasitism by this does not exceed 15.7% (PILLAI & NAIR, 1982b).

B. nephantidis mates easily in laboratory cages. Compared to *B. nosatoi* it is more capable of maintaining its population in areas that are colonised by the ichneumonids, *X. punctata* and *X. nana nana*. In high humid areas near the sea shore, it often produces higher proportion of female progeny (1 male 9 females). Although oligophagous, it prefers *O. arenosella* and continues to breed in it throughout the year. It can develop in host pupae which are in the advanced stages of development as well. In areas where parasitism by *B. nosatoi* is low (eg. Badagara, Kerala) or it is absent (eg. Salem, Tamil Nadu) *B. nephantidis* has failed to take advantage of the situation to build-up its population and to suppress outbreaks of *O. arenosella* (JOY & JOSEPH, 1977a, 1977b; PILLAI & NAIR, 1989). *B. nephantidis* often acts as a facultative hyperparasitoid of *Eriborus trochanteratus* (Morley) (PILLAI & NAIR, 1986a), *Apanteles taragamae* Wilkinson and *Stomatomyia bezziana* Baranoff.

It cannot withstand continuous drought conditions. Depletion of its population occurred in Kerala during the drought period of 1982–1983. Only very few adults of *B. nephantidis* emerged from the field-collected pupae of *O. arenosella* during April to August, 1983.

Courtship and mating :

Females mate on the day they emerge or on the subsequent days, with the earlier emerged males. The courtship behaviours of *B. nephantidis* are similar to *B. nosatoi*, except steps 3, 4 and 7. The male does not rock the female or rub on the wings, but only presses the wings with the closely held antennae. It stands tall on its hind legs on becoming excited and presses the wings with maximum

TABLE 1. Life history or *Brachymeria* spp.

	B. nosatoi	*B. nephantidis*	*B. atteviae*
Pre-oviposition period (days)	4 to 5	3 to 5	4 to 5
Egg period (hours)	23 to 24	24	23.5 to 28.0
Larval period (days)	5 to 9	5 to 10	5 to 8
Pupal period (days)	6 to 10	6 to 10	6 to 9
Egg to adult periods (days)	12 to 20	12 to 20	12 to 18
Majority adult emergence (days)	14 to 18	14 to 18	14 to 16
Sex – ratio (male : female)	1 : 2.5	1 : 1.35	1 : 2
Longevity of adults (days)	30 to 115	30 to 93	30 to 155

strength. The female raises the abdomen and exposes the genital pocket. Keeping the metathoracic legs on the substratum and holding the female with the other legs, the male mates with 4 to 8 jerks. Mating lasts for 4–7 seconds.

Rearing of *B. nephantidis* in the laboratory is very easy as it accepts pupae with or without cocoon. In excised *O. arenosella* pupae, oviposition is effortless and quick, normally taking 3 to 4 minutes against 35 to 40 minutes to make a hole and oviposit in pupae which remain within cocoons. However, SATPATHY & RAO (1972) did not observe *B. nephantidis* ovipositing in naked pupae.

H. nigrivitta and *Phalacra vidhisaria* Walker (Lepidoptera: Drepanidae), a foliage feeding pest of coconut, were also recorded as hosts of *B. nephantidis*.

Brachymeria lasus (Walker)

Various aspects of this highly polyphagous species were studied in detail by NARENDRAN & JOSEPH (1976a). Besides *O. arenosella*, its hosts include many serious crop pests such as the cotton boll worms *Pectinophora gossypiella* (Sound), *Earias* spp., the teak skeletoniser, *Hapalia machaeralis* (Wlk.) and the rice skipper *Pelopidas mathias* (F.) (NARENDRAN & JOSEPH, 1976c.). As the quantity of nourishment available in the pupae of *O. arenosella* is quite inadequate for the development of *B. lasus*, more number of male progeny than females are produced when it parasitises *O. arenosella* pupae (NARENDRAN & JOSEPH, 1976b). The average parasitism by it does not exceed 0.22% to 1.33% (PILLAI & NAIR, 1981). During July-September, the pupae of *Anadevidia peponis* (F.) were observed to be heavily parasitised by *B. lasus* under field conditions and mostly female parasitoids emerged from them.

Courtship and mating:

The females mated on the day of emergence or on the subsequent days. The males of *B. lasus* are more vigorous than those of *B. nosatoi*, *B. nephantidis* and *B. atteviae*. The males in courtship lower and raise their abdomen, sway their heads and fan their wings. In some cases only the forewings are fanned. If the female kicks, the male may go to the front and tap on the head of the female with his anteannae. Circling round the female swaying is uncommon although the male makes vigorous quarter or semicircling movements. The male in courtship follows the female from the rear through the same path on which the female was moving. The female keeps her antennae almost vertically and cleans her wings and body during courtship. Standing behind the female, the male keeps his antennae apart without touching one another and keeps them over the wing and applies more downward pressure at frequent intervals with the base of the scape and pedical and rocks the female occasionally. Under the stereomicroscope slight downward and then upward rubbing on the wing with antennae could be observed. The male mates without jerks for 6 to 8 seconds.

B. lasus completed its life cycle in 12–18 days and the adult longevity upto 100 days was recorded.

Brachymeria atteviae Joseph, Narendran & Joy

Intensity of parasitism by *B atteviae* was higher at Salem, Tamil Nadu, where it parasitised 7.12% pupae (25/351) of *O. arenosella* in 1981 (PILLAI & NAIR, 1989). This oligophagous species is distributed in north and south India and it parasitises *Atteva fabriciella* Swed., *H. machaeralis* etc. (NARENDRAN, 1985).

Courtship and mating:

1. The male sways the front part of the body in sexual excitement, lowers and raises its abdomen, approaches the female from the rear and attempts to stop her with the antennae.

2. The unreceptive female folds and keeps her antenae behind her head and kicks.

3. Then the male makes swaying movements around the female in quarter, semi or in full circles like *B. nosatoi*, He may also stand face to face with the female and may rub on the head or tap at the thorax of the female with the antennae and then move to the rear to resume wing pressing.

4. With the closely held and anteriorly projected antennae, kept on the middle of the abdomen of the female, over the wings, the male applies pressure, rocks the female occasionally and rubs the wings downwards and upwards. After some time, the male becomes more excited and standing tall on the hind legs, it applies maximum downward pressure rocking the females and rubbing on the wings.

5. The female, raising the abdomen, exposes the genital pocket and holding the famle, mates with 8 to 29 jerks for 6 to 12 seconds. During each jerking, the male fans his wings.

6. The female terminates mating. The virgin female mates even 8 days after emergence.

Oviposition:

Like *B. nephantidis* and *B. lasus*, it also makes a hold in the cocoon, when pupae of *O. arenosella* along with the cocoons are offered for oviposition. Unmated females produced male progeny. Laboratory rearing is easy as it accepts naked host pupae also.

Hosts recorded include *Gangara thyrsis* Moore, *H. nigrivitta* and *P. vidhisaria*.

Antrocephalus hakonensis (Ashm).

A hakonensis, on an average, parasitises less than 1% pupae of *O. arenosella* in the field, and as such, is only an unimportant parasitoid of the pest. However, it was observed as a dominant species of parasitoid of *H. nigrivitta* infesting dry coconut leaves used in thatch or fencing. Moreover, it appears to prefer host in dried leaves rather than in green leves. In *H. nigrivitta*, the extent of parasitism by *A. hakonensis* went up to 31.25% (25/80 pupae) at Kayangulam, Kerala. This parasitoid was studied in detail by ABDURAHIMAN *et al.* (1983).

Salilent features of A. hakonensis :

This parasitoid is amenable to laboratory multiplication. Courtship is simple and there is no selection of males. The females mate immediately on emergence. Females are monandrous, but incomplete sperm transfer leads to a second mating, which was not, so far, observed in *Brachymeria spp.* The male courts the female with antennal to antennal contact on mounting. The males are aggressive and polygynous.

A. hakonensis also acts as a hyperparasitoid by ovipositing on *Apanteles taragamae* Wilkinson in the field. Puny males emerge from such cocoons. Life cycle is longer than that of *Brachymeria* spp. and longevity of adults is almost comparable to that of *Brachymeria* spp.

Courtship and mating :

There are three interesting aspects about the courtship and mating behaviours of *A. kakonensis.*

1) The virgin females always mate afer a brief resistance.

2) The first male that mounts the virgin female always succeds in mating. If the male is thrown out of her body, he immediately remounts and resumes antennation.

3) After termination of mating, the exhausted male crashes on the substratum and remains motionless for a while, after which he moves away.

On mounting the virgin female, the older male proceeds towards her head and makes contact with her antennae. Her antennae are brought to a near horizontal plane with her body and antennates in two ways.

The most common type of antennation is as described by MATHEWS (1975) in the case of the cynipid, *Diastrophus* nebulosus which produces knot gall on wild black berry, *Rubus* sp. "The male alternately strokes the inner side of each of the female's antennae with the outerside of his own corresponding antennae". The point of actual contact could not be determined. The antennation is at an average rate of 1.5 strokes per second and it lasts for 34 seconds (range 14 to 76 seconds). When the female elevates the abdomen and exposes the genital pocket the male hurriedly backs up and mates with jerking after assuming a vertical position behind the female. During mating, the male does not hold the female with his legs, but balances with the movement of his wings. It mates for 31 seconds (range 25 to 34 seconds) with 48 jerks (range 39–63). Mating is terminated by the female by virtually removing the male with her hind legs and the exhausted male crashes on the substratum for a while.

The second type of antennation is the sweeping of the antennae of the female as observed by ABDURAHIMAN *et al.* (1983).

Life cycle:

The life cycle is normally completed in 16 to 23 days, but rarely it extends up to 29 days. Adults lived for 30 to 105 days. Sex ratio of parasitoids emerged from field-collected *O. arenosella* pupae was 1:3 (Male : Female).

DISCUSSION

Among the several indigenous pupal parasitoids of *O. arenosella*, *B. nosatoi* is the most useful parasitoid and *B. nephantids* the second best. *B. nosatoi* has many outstanding qualities of an ideal biocontrol agent. Unlike the other species of *Brachymeria*, it does not act as a facultative hyperparasiticid. High summer temperatures and prolonged drought have no adverse effect on the rate of its multiplication. These qualities are seldom found in other species of parasitoids. *B. nosatoi* exerts strong regulatory pressure and its effect on the pest population is not highly variable. Although it was thought to be not amenable to laboratory multiplication. It can be reared in sufficient numbers in the laboratory using the method described by PILLAI & NAIR (1982*a*). Unfortunately, this species is scarce is North Kerala tracts. It will be interesting to study the factors responsible for the low percentage of its parasitism in North Kerala. *O. arenosella* is such a pest which can cause frequent outbreaks and extensive damage to coconut plantations and in south Kerala, this is averted to a great extent, by the activity of *B. nosatoi*, which is capable of suppressing nearly one third of the pupal populations.

B. nephantidis is widely distributed in India, but it suppresses only nearly one sixth of the pupal population of *O. arenosella* in south Kerala. Outbreaks of *O. arenosella* occur in areas where *B. nephantidis* is present without *B. nosatoi* (JOY & JOSEPH, 1977b).

B. lasus, *B. atteviae* and *A. hakonensis* are not significant species of parasitoids of *O. arenosella* in Kerala. However, parasitism by *B. atteviae* was observed to be significant at Salem, Tamil Nadu.

Courtship behaviour among *Brachymeria* includes wing fanning, lowering and raising of abdomen, swaying the front part of the body wing pressing and applying intermittent downward pressure, rocking the female and rubbing on the wings downwards and upwards or *vice versa*. Insemination is with jerking or without jerking. In *B. nosatoi*, courtship is very elaborate, selection of males also is rigid, and hence it is genetically wise. On the other hand, courtship in *A. hakonensis* is simple and it mates with the first male that happened to mount her, indicting that it is genetically unwise. Although monandrous like *Brachymeria*, inadequate insemination induces *A. hakonensis* immediately to mate for a second time.

Under identical conditions of temperatures and relative humidity, the life cycle of all the four species of *Brachymeria* is almost identical.

In areas where *Xanthopimpla nana nana* Schulz and *X. punctata* are dominant, *B. nosatoi* is unable to build up its population (PILLAI & NAIR, 1989). However *Xanthopimpla* spp. colonise only in selected territories towards the latter half of the year and they also do not uniformly disperse in all the *Opisina*- infested coconut gardens. Biological suppression of *O. arenosella* can be achieved to a very great extent by getting *B. nosatoi* established in areas where it does not occur at present. Augmentation of the population of *B. nosatoi* in north Kerala tracts will reduce the incidence of *O. arenosella* in that region.

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BOOK REVIEW

APPLIED ENTOMOLOGY By P. G. FENEMORE and ALKA PRAKASH, Wiley Eastern, New Delhi, Paper-back, 298 pp., 1992.

The authors' object in writing this book has been to provide students, practising agriculturists and horticulturists and other interested persons with basic introduction to insects and to the principles and practice of pest control, and the authors have succeeded in doing that. The book has been well planned and includes a brief introductory chapter plus nineteen chapters which deal with structure and function; growth, development and metamorphosis; reproduction and life cycles; classification; predators, parasites and pathogens; ecological background to pest control; principles and practice of pest control; lac-, silk-, and apiculture; storage of foodgrains in India; bionomics; control of selected insect pests of crops and stored grains; household insects; and collection, preservation and culture of insects. There is also a chapter on mites and other non-insect pests, as well as one on insects and plants. In addition it gives a useful catalogue of insecticides and acaricides with their common names, trade names, acute mammalian toxicity, main uses etc. and has also glossary and index. The book is adequately illustrated with suitable explanation of figures. Mistakes are rare and it can be confidently recommended to students. The book will be useful to undergraduates; post-graduates may also find it useful. The book can be recommended for Zoology and Entomology libraries in colleges and universities.

V. K. K. PRABHU

PEST MANAGEMENT IN TEA, By M. MURALEEDHARAN, published by The United Planters' Association of Southern India, Valparai, Coimbatore Dist., hard-bound, 130 pp., 1991.

The book Pest Management in Tea written by N. MURALEEDHARAN, fills the lacuna of a book for beginners of research on tea pests, and would also serve as a field guide on tea pests and their management. It deals with not only insect pests of the tea plant, but mites and even non-arthropod pests viz., nematodes and rodents. It includes accounts of the concept of pest management, pesticides and their formulations, safety precautions in handling pesticides, first-aid treatment, recommendations of pesticides and their dosage against specific pests, and toxicity of pesticides used for control of pests on tea. It has also a list of references, author index, species index and subject index. The book is sufficiently well illustrated with explanation of figures, and is written in simple and lucid style with very few mistakes, and will definitely serve its purpose. It will also be useful addition to any Zoology - and Entomology library.

V. K. K. PRABHU

BIOLOGY OF INSECTS, By S. C. SAXENA, Oxford & IBH Publishing Co. Pvt. Ltd. New Delhi, paper-back, 366 pp., 1992, Rs. 89/-.

The book Biology of Insects, written by S. C. SAXENA, touches almost all aspects of insects: distribution of insects in space and time, their origin and diversity ie., classification, structure and function, development and growth, ecology, principles of insect control covering almost all major aspects, a list of references and a subject index. The

major portion, in fact almost half, is devoted to principles of insect control, of which more than 50 pages concern synthetic insecticides. According to the author, the book is meant for Bachelors, Honours and Masters degree students of Faculties of Science and Agriculture endeavouring to provide almost complete knowledge of the important and common aspects of insect science required at their level. This has of course been too ambitious. In attempting to cover too much in too few pages, the tendency is for generalisation. Treatment is such that at places it presupposes considerable knowledge of entomology among its readers, but at places it becomes too elementary. Though there are quite a few figures they are not accompanied by explanation of figures and one has to wade through relevant portions of the text for that purpose. Citation of figures is often not precise; sometimes it turns out to be wrong also, as in the case of Fig. 10 which shows different types of antennae, most of them indicated wrongly. One wishes more care was taken in bringing out this book and the large number of mistakes avoided.

V.K.K. PRABHU

THE BEETLE BLUNDER, By K. V. NARENDRA, Centre for Science and Technology, Bangalore, 20 pp., Rs. 20/-.

This is a popular book by the author drawing attention to the possible dangerous consequences of introducing foreign bio-control agents without careful and thorough investigation. The author claims that introduction of the Mexican beetle *Zygogramma bicolorata* Pollister to control *Parthenium hysterophorus* L in India is likely to prove dangerous to sunflower crop and hence cautions against its use.

V. K. K. PRABHU

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AUTHOR INDEX

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